LANDMARKS IN THE URETER.

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General Remarks.

The data of the following article are based on the investigations of over 100 ureters of man, ape, monkey, dog, cat, rabbit, horse, cow, pig, sheep, leopard, and fish. The ureter was distended with air, fluid-melted paraffin, red lead, and starch, and finally X-rayed as a model for drawing. Ureteral dissection was practised to confirm data.

Surgery is the father of anatomy. Previous to the demonstrated utility of ureteral surgery, the practical anatomy of the ureters remained unknown precisely similar to that of the utero-ovarian artery. My experience in gynæcology with special regard to relation of the ureter and the utero-ovarian vascular circle, and particularly the advance in the diagnosis of ureteral disease by the aid of the X-ray, induced me to make a special study of the anatomy and physiology of the ureter (chiefly in the female) for practical and surgical purposes. The ureter is significant in abdominal and pelvic surgery, but it is of special practical importance in its relation to the pelvic-floor segment of the utero-ovarian artery at the distal arterio-ureteral crossing.

The ureter is not a straight, uniform calibered tube, but consists in general of three constant dilatations (reservoirs, spindles), three constant constrictions (sphincters, isthmuses), and three constant flexures (curves),—all of which are important in practical surgery.

Causes of the ureteral dilatations: the ureteral pelvic dilatation is due to a flexure, kink, of the ureter (neck) caused by a medialward projection of the distal renal pole; the lumbar dilatation (spindle) is due to the bending of the ureter over the iliac artery resulting from the erect attitude (man and ape); quadrupeds do not possess this ureteral spindle or dilatation. The pelvic dilatation (spindle) is due to resistance of the valve in the bladder-wall. The flexures of the ureter produce the ureteral isthmuses or sphincters, and these constrictions cause ureteral dilatations. The constrictions in the ureters obstruct calculi. The X-ray demonstrates that more calculi are found in the ureter than in the kidney. The calculi will lodge at the points of narrowest caliber of the ureter which are in order, perhaps; (*a*) the proximal isthmuses (neck); (*b*) the distal isthmus or vesical ureteral orifice, and (*c*) the middle ureteral isthmus at the iliac flexure. The ureter, consisting of calices, pelvis, and ureter proper, is as independent an organ as the heart, uterus, or lung. It is not a passive organ. It is an active, rhythmical viscus, dilating and contracting like the uterus, heart, and lung. Its complete single rhythm (dilatations and contractions), extending from calices to bladder, occupies, perhaps, five minutes. Urine passes from kidney to bladder by ureteral rhythm, peristalsis, not by attitude or force of gravity. All late developed organs are frequently subject to anomalies. The ureter is the third renal duct arising from the Wolffian body, and hence has numerous anomalies, especially extra mucal valves, and consequent irregular dilatations. The proximal end is especially liable to irregularities.

To record accurately the views acquired by the investigation of the ureter and to facilitate the comprehension of ureteral relations, sphincters, dilatations, curves, and new nomenclature, we present a number of illustrations based on the solid ground of nature.

The ureter, a urinal transporting organ, lies interpolated between kidney and bladder. It is a rhythmical, active, independent, not a passive organ. The ureter is not only a transporting urinal duct, but it is also a urinal reservoir exactly

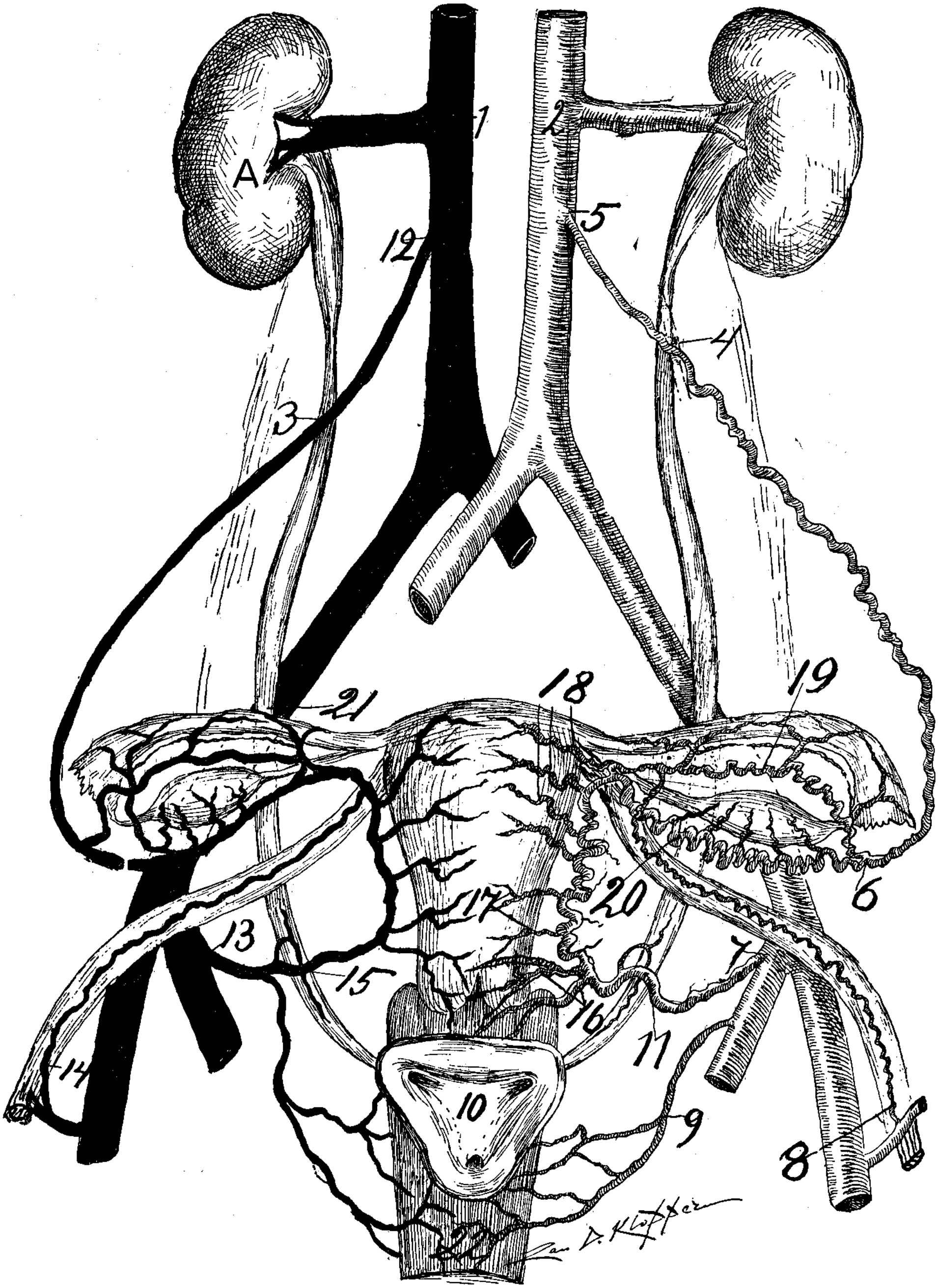


FIG. 1.—Ureteral relations to the tractus genitalis and to the utero-ovarian vascular circle. 7. Origin of arteria uterina. 11. The distal arterio-ureteral crossing (with its arteria ureterica). 21. Middle arterio-ureteral crossing. 3 and 4. Proximal arterio-ureteral crossing (where there is a constant arteria ureterica). On the right side is the uretero-venous triangle of author (3, 12, 11). Trigonum vesicæ, 10.

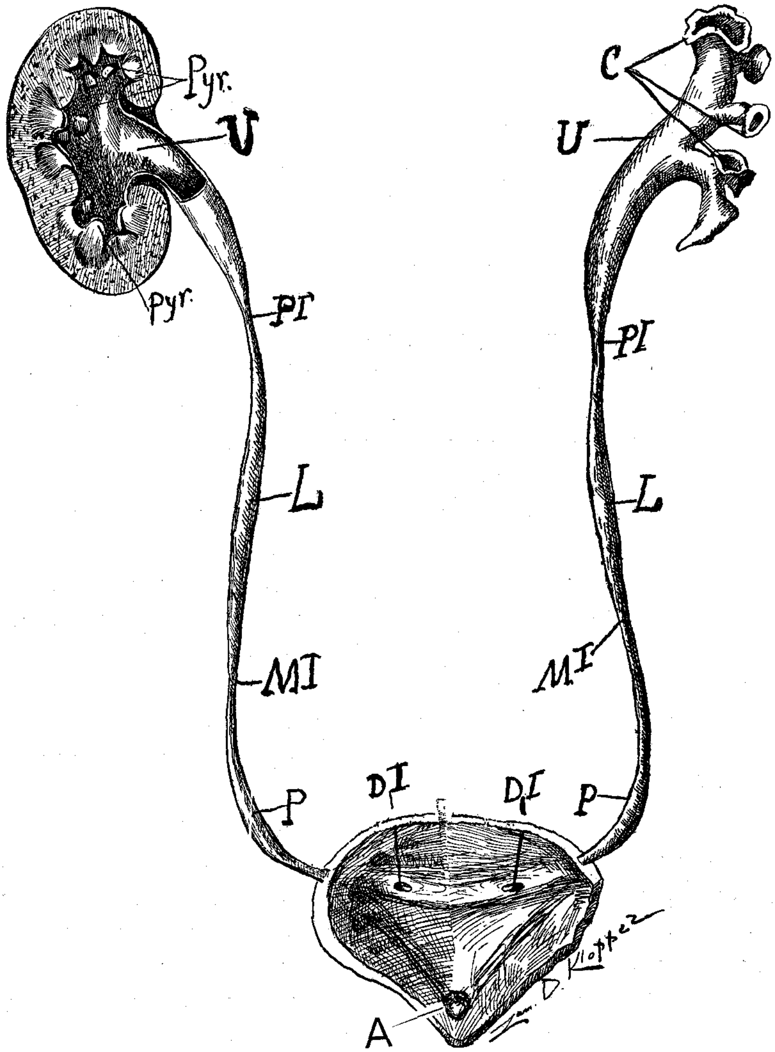


FIG. 2.—Illustration of female ureters in their natural course. C. Calices, with their major proximal and distal arms. U. Ureteral pelvis (reservoir). PI. Proximal isthmus (ureteral neck). L. Lumbar spindle (reservoir). MI. Middle isthmus, sphincter. P. Pelvic spindle. DI. Distal isthmus, sphincter. Pyr. Renal pyramids. The trigonum vesicæ is plainly visible, DI. DI. A.

similar to the bladder, which is periodically rhythmically distended and contracted. The ureter is a segment of a perfect system of water-works, of which the reservoirs and stop-cocks are always full and in order. The ureter fills and empties its contents by rhythmical waves regardless of attitude. The capacity of the ureter (calices and pelvis) in some cases is about an ounce. The muscularis of the ureter (tractus urinarius) consists of several, generally three, irregular layers resembling the three irregular muscular layers of the tractus genitalis (oviducts, uterus, vagina). The muscularis of the tractus intestinalis consists of two constant muscular layers, an internal circular and external longitudinal muscular layer.

The ureter resembles a river whose contributory arms or calices collect the fluid from different regions of the kidney to merge into the main stream bed, the ureteral pelvis, whence the ureter conducts it to the bladder. The urine is continually prepared and secreted by the kidney, but the ureter (a reservoir) conducts it to the bladder (a reservoir) periodically only, when the ureteral calices and ureteral pelvis are filled, *i.e.,* by ureteral rhythmical waves. The ureters are distensible but slightly elastic. In the cadaver they will distend, but not recover their form, by elasticity. Intimate fixed connections of the ureter with any organ do not exist except with the kidney and bladder. It is fixed slightly by some fibres to the peritoneum. The distal and proximal extremities of the ureter are located in vast beds of areolar tissue,—important for mobility and surgical intervention. The ureters are soft organs and not easy to feel. The defects in the ureters lie either in the obstruction of the urinal stream (mechanical, kink, stricture, calculi) or in their peristalsis (paralysis of inflamed wall). A ureter being considerably longer than the distance between the proximal and distal extremities, and lying in a universally loose matrix of areolar tissue, can be lifted several inches from its bed, drawn through an abdominal wound or forced aside by pathologic processes, without loss of integrity. All surgery on the ureter should be executed as near the ureteral reservoirs as possible, on account of large caliber and ample ureteral wall.

In special relations of the ureters, the left ureter, on account of its nearer approach to the middle line, lies closer to the cervix uteri and to the aorta. The more distal the uterus the closer are the ureters to it; hence, in vaginal hysterectomy, to avoid ureteral trauma, the ureters should be forced ventrally and proximally by cleaving the bladder from the uterus. The filling of the bladder separates the ureters, removes them from the ventral pelvic wall, and forces them proximalward. Under some circumstances the ureter may be palpated through the vagina, rectum, or on the iliac vessels. The ureter should be sought on the ventral vaginal wall from the proximal end of the columna vaginales to the ventral vaginal wall. Through the rectum one seeks the ureter between the lateral pelvic wall and lateral vaginal fornix.

The following table of ureteral function and structure will facilitate the comprehension of the field of the ureter in the individual economy.

FUNCTION.	I. Tunica Mucosa.	1. Secretion. 2. Absorption.	*a.* Beaker cell (?). *b.* Glands, crypts (?).
	II. Tunica Muscularis.	1. Peristalsis (rhythm).	*a.* Muscular contraction and relaxation. *b.* Rhythmical ureteral waves.
	III. Tunica Fibrosa.	1. Distributing medium.	*a.* Blood-vessels. *b.* Lymph vessels. *c.* Nerves. *d.* Ganglia.
		2. Elastic medium,—areolar cushion.	
		3. Fascial fixation apparatus.	
		4. It lies in planes of subserosa.	
	IV. Tunica Serosa (Partial).	1. Absorption. 2. Secretion. 3. Facilitates motion. 4. Fixation apparatus.	

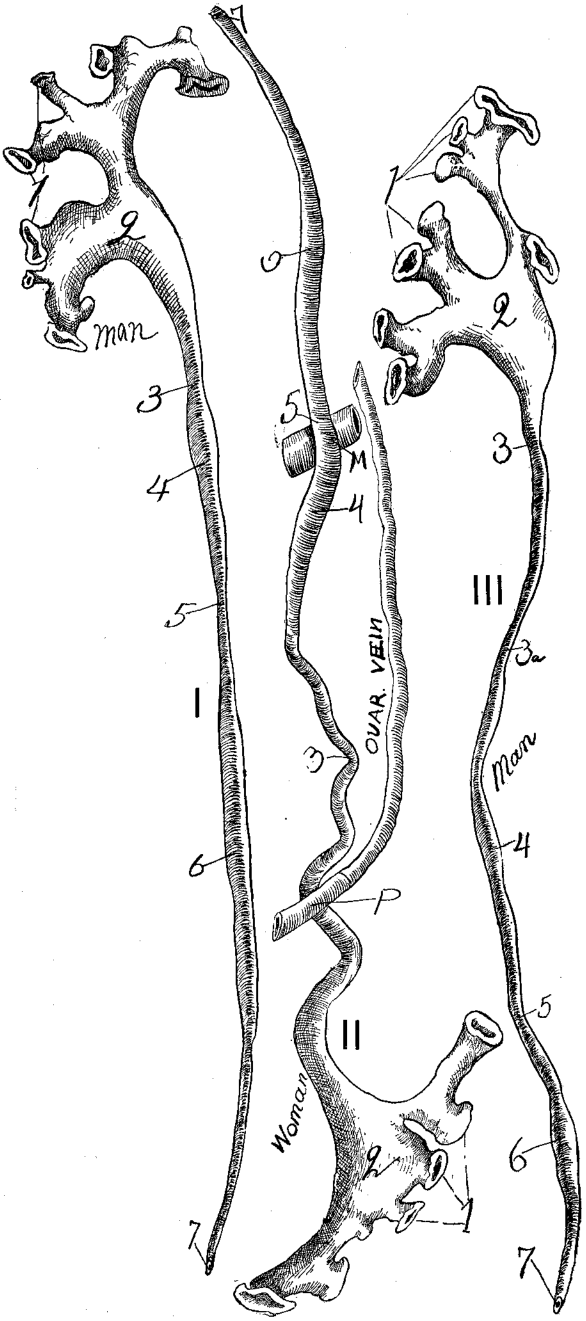
(The general function of the ureter is peristalsis, absorption, and secretion.)

FIG. 3.—As the ureteral calices, pelvis, isthmuses, reservoirs, spindles, and arterio-ureteral crossings of each drawing are numbered alike, one description suffices for all.

1. Ureteral calices. 2. Ureteral pelvis (reservoir). 3. Proximal ureteral isthmus, sphincter, or neck. 4. Lumbar spindle (urinal reservoir). 5. Middle isthmus, sphincter (flexura iliaca ureteris). 6. Pelvic ureteral spindle (reservoir), generally two, marked 6 and 6a. 7. Distal ureteral isthmus, sphincter, or distal ureteral orifice. M indicates the point of the ureter crossing the iliac artery—middle arterio-ureteral crossing. P notes the proximal and Q (a) the distal arterio-ureteral crossing. Unless otherwise stated, the ureters were removed from the cadaver with the dorsal tissue, vessels, kidneys, and internal genitals in order to retain natural relations; after which I injected ureters and vessels with red lead and starch of similar consistency and under similar pressure. The specimens were then X-rayed in Dr. Harry P. Pratt's X-Ray and Electro-Therapeutic Laboratory. Dr. Wm. E. Holland magnified the X-ray three times the original or natural size of the specimen, when my artist, Mr. Zan D. Klopper, sketched from this as a model. The illustrations accompanying the article are, except when noted, reduced to seven inches long,—one inch over half-life size.

FIG. 3 presents three isolated ureters. Note the wide range of variation not only in the calices, the proximal and distal arms, but the irregular ureteral spindles and isthmuses.

Fig. 3.



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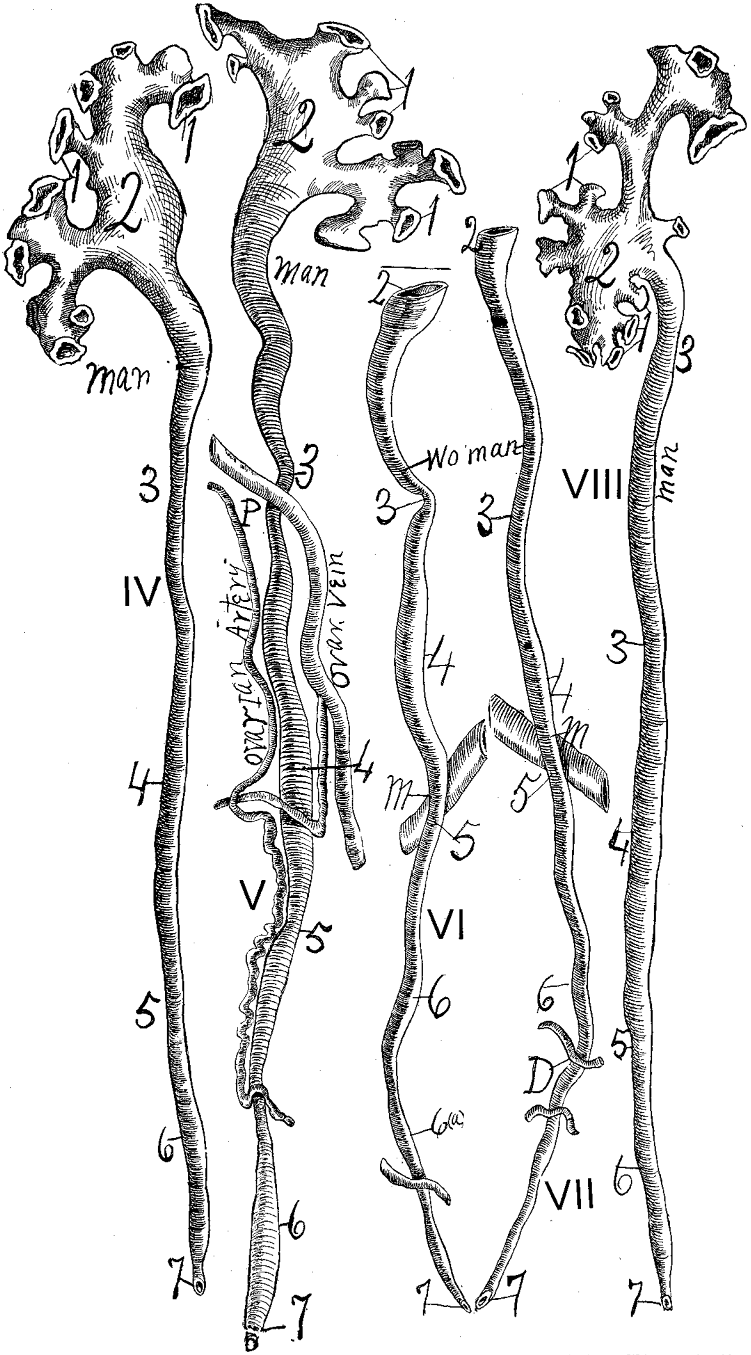


FIG. 4.—Five ureters, three with and two without calices and pelvis. The spindles are obvious, especially those of the woman at 4 and 6. There frequently exist two pelvic spindles, 6 and 6a. VI and VII are ureters from the same subject in their natural course relations. Observe the variation in ureteral calices and pelvis. The major distal arm of the calices is practically a lateral tributary, while the major proximal arm of the calices is the principal in direction; however, the proximal arm generally has one or two less calices.

STRUCTURE.
- I. TUNICA MUCOSA. EPITHELIUM.
  - 1. Form, transitional.
  - 2. Layers,—multiple, usually three.
  - 3. Shape,—cylindrical (flat), polyhedral, cubical, oval.
  - 4. Nucleus,—oval.
  - 5. Beaker cells (?).
  - 6. Glands, crypts (?).
  - 7. Lies in longitudinal folds.
- II. TUNICA MUSCULARIS.
  - 1. Internal longitudinal layer.
  - 2. External circular layer.
  - 3. Irregularly directed muscular bundles.
  - 4. Ureteral fibromuscular sheath.
  - 5. Numerous lymph, large blood-vessels (especially veins) exist in this coat.
- III. TUNICA FIBROSA.
  - 1. Areolar tissue (fat).
  - 2. Fascial fibre.
  - 3. Elastic fibre.
  - 4. Chief location of main ganglia and nerve cords.
  - 5. The fibrous tissue of the ureter (like that of the genitals) possesses large veins.
- IV. TUNICA SEROSA (PARTIAL).
  - 1. Endothelium.
  - 2. Stomata vera.
  - 3. Stomata spuria.
  - 4. Interendothelial line.
- (General structure: (*a*) mucosa; (*b*) muscularis; (*c*) fibrosa.)

Object.—A transporting urinal duct from kidney to bladder.

Accessory Glands.—Crypts, glands(?).

Composition of Secretions.—Mucus, fluid.

Nerve Apparatus.—The ureter is supplied by 1. Plexus renalis and 2. Plexus ovarica, chief supply to the proximal ureter. 3. Plexus hypogastricus and 4. Plexus vesicalis, chief supply to the distal ureter. 5. The main nerve supply of the ureter is from the sympathetic; hence the ureter is an active rhythmical organ, as sympathetic nerves alone produce rhythm. 6. The large sympathetic nerve ganglia reside in the tunica fibrosa ureteris. 7. Non-sympathetic nerves also are found in the ureter. 8. The main nerve supply of the ureter is found along the ureteral blood-vessels, and is designed to innervate the tunica muscularis. 9. A nerve net-work surrounds the ureter.

Vascular Apparatus.—(A. Arteries.) The ureter is supplied by the following arteries, viz.: 1. Arteria renalis; 2. Arteria ovarica (Arteria ureterica proximal); 3. Arteria iliaca (Arteria ureterica media); 4. Arteria uterina (Arteria ureterica distal); 5. Arteriæ vaginales; 6. Arteria hæmorrhoidalis media; 7. Arteria vesicalis inferior; 8. Arteria nutrientia pelvis.

(B. Veins.) The ureter is drained by the following veins: 1. Plexus venosus renalis. 2. Plexus venosus ovarica. 3. Branches to vena iliaca. 4. Branches to vena hypogastrica. 5. Branches to plexus venosus vesicalis. 6. A net-work of large vein lies in the tunica fibrosa ureteris.

Lymph Apparatus.—Little is known of the lymph apparatus of man's ureter. Krause, 1876, makes a statement that there is a lymph net-work in the ureteral mucosa. Perhaps the space between the extra distal muscular ureteral sheath and ureter proper is of a lymphatic character.

The segments of the ureter are significant for detailed views and surgical intervention.

- SEGMENTS.
  - I. ANATOMIC AND PHYSIOLOGIC.
    - 1. Ureteral calices.
    - 2. Ureteral pelvis.
    - 3. Ureter proper.
  - II. REGIONAL.
    - 1. Pars abdominalis.
      - *a.* Pars renalis or adrenalis.
        - *A.* Ureteral calices.
        - *B.* Ureteral pelvis.
      - *b.* Pars infrarenalis or pars lumbalis.
    - 2. Pars iliaca (flexura iliaca ureteris).
    - 3. Pars pelvina.
      - *a.* Pars parietalis (fixed).
      - *b.* Pars vesicalis (mobile).
        - *A.* Pars extramuralis.
        - *B.* Pars intramuralis.
  - III. SURGICAL.
    - 1. Dilatations (reservoir, spindles).
      - *a.* Ureteral pelvis (proximal).
      - *b.* Lumbar spindle (middle).
      - *c.* Pelvic spindle (distal).
    - 2. Constrictions (isthmuses, sphincters).
      - *a.* Proximal (neck).
      - *b.* Middle (iliac).
      - *c.* Distal (vesical).
    - 3. Flexures (curves).
      - *a.* Flexura renalis (due to distal renal pole).
      - *b.* Flexura iliaca (due to iliac vessels).
      - *c.* Flexura pelvina (due to pelvic organs).

Fixation Apparatus.—The ureter is fixed by (1) the kidney; (2) the bladder; (3) by a universal loose bed of areolar and fascial tissue; (4) the peritoneum; (5) blood-vessels and nerves; (6) adjacent viscera; (7) intra-abdominal pressure. An intimate fixation apparatus of the ureter does not exist except at the kidney and bladder. The ureter is a mobile, shiftable, extraperitoneal organ universally loosely embedded in the dorsal subserosum. The ureter being longer than the distance between kidney and bladder, also lying in a loose, mobile bed, it may be drawn through an abdominal incision without injury.

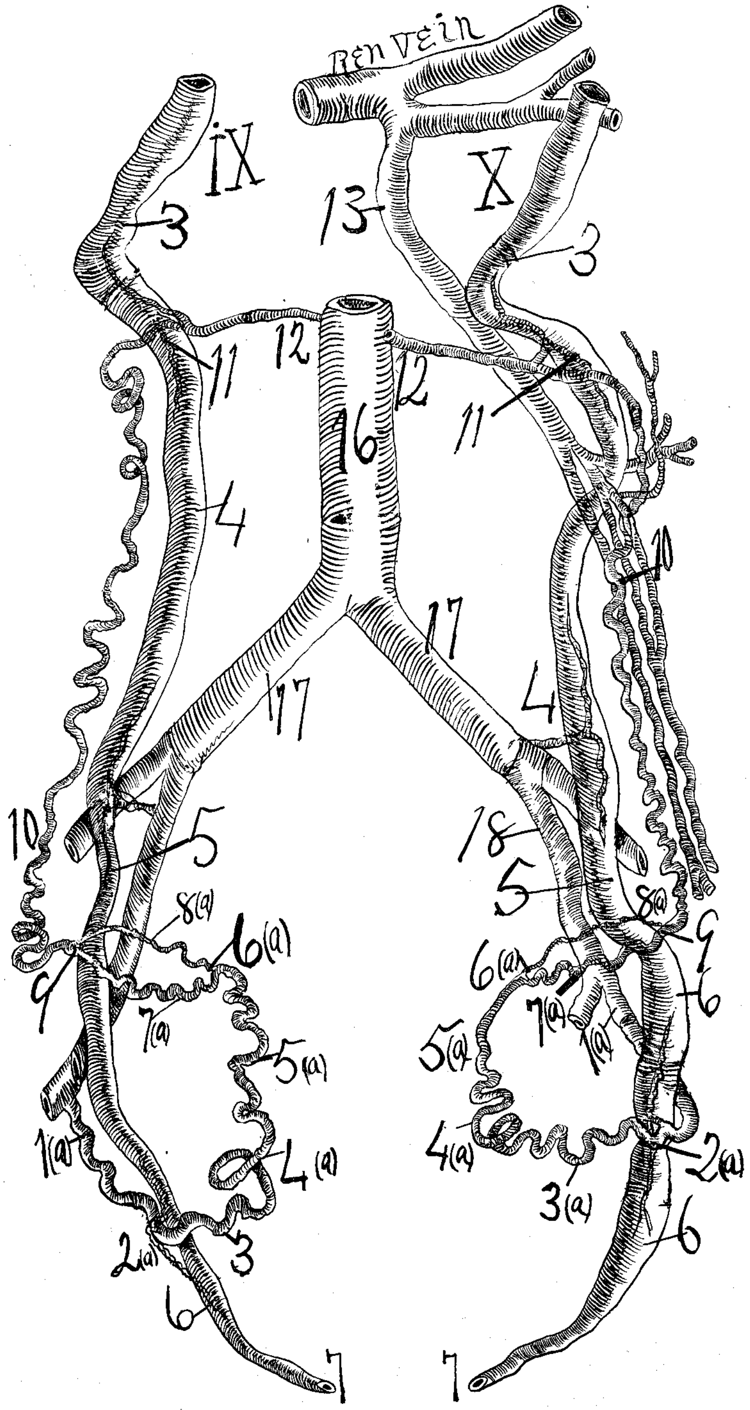
Walls.—(*a*) Ventral; (*b*) Dorsal; (*c*) Lateral.

DIMENSIONS.

1. Length.	male	11½ inches.
	female	11 inches.
2. The left ureter is about one-half of an inch longer than the right.		
3. Distance.	(*a*) between ureteral pelves	4 inches.
	(*b*) (maximum) between pelvic ureters	4½ inches.
	(*c*) between distal ureteral orifices	1 inch.
4. Distance between ureters at the arterio-ureteral crossings.	(*a*) Proximal	3½ inches.
	(*b*) Middle	2½ inches.
	(*c*) Distal	2½ inches.
5. Diameter (isthmuses, sphincters).	(*a*) Proximal	$\frac{1}{7}$ inch.
	(*b*) Middle	¼ inch.
	(*c*) Distal	$\frac{1}{10}$ inch.
6. Diameter (reservoirs).	(*a*) Ureteral calyx	¼ inch.
	(*b*) Ureteral pelvis	½ by 1½ inches.
	(*c*) Lumbar spindle	⅓ inch.
	(*d*) Pelvis spindle	¼ inch.
7. Distance of ureter from cervix uteri		½ inch.
8. Distance between ureters at os internum uteri		2½ inches.
9. Distance between hilus renis to proximal isthmus		½ to 4 inches.
10. Distance (minimum) between ureter and rectum		¼ inch.
11. Distance between ureters at os uteri externum		2 inches.
12. Distance between ureters on entering bladder		1½ inches.
13. Length.	(*a*) Pars abdominalis	5 inches.
	(*b*) Pars iliaca	1 inch.
	(*c*) Pars pelvina	5 inches.
14. Length.	(*a*) Lumbar spindle	1 to 3 inches.
	(*b*) Pelvic spindle	½ to 1½ inches.

FIG. 5.—Ureters in relation to utero-ovarian vascular circle, 1 (a), 2 (a), 3 (a), 4 (a), 5 (a), 6 (a), 7 (a), 8 (a), 9, 10, 11, 12. At 2 (a) the distal arterio-ureteral crossing the distal arteria ureterica passes from the arteria uterina to supply the ureter. IX and X from the same subject. At 11, the proximal arterio-ureteral crossing, the ovarian segment emits the proximal arteria ureterica to supply the ureter, the arteria ureterica having age and functional relations, its lateral branches will also possess age and functional relations, consequently the walls of the ureter at the arterio-ureteral crossing will possess age and functional relations, and hence suffer in nourishment and dilate in climacterium and senescence. The ureters show different sized dilatations and sphincters in this subject. Both ureters cross the common iliaces at the middle arterio-ureteral crossings, which of course will show no recognizable age and functional relations. 13. Ovarian vein. No. X presents the uretero-venous triangle of the author by means of the ovarian vein (13, 11), ureter (11, 3, to kidney), and the renal vein. X shows wide spindle dilatations.

FIG. 5.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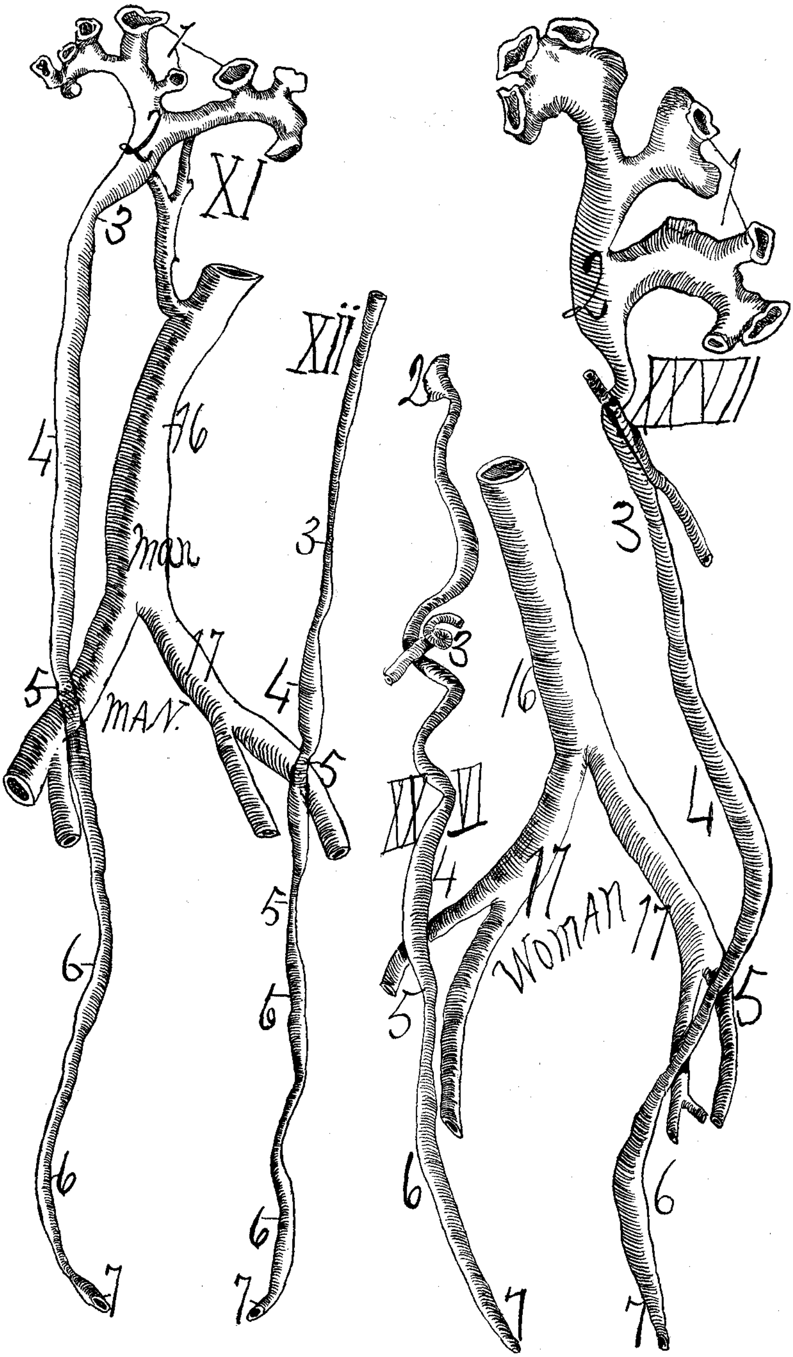

FIG. 6.—Nos. XI, XII are from the same subject as are XXVI and XXVII. The spindles in the same subject differ in size and location in each ureter, but they are governed in general by the original isthmuses; however, the ureter being in a loose bed, and gaining its adult location by a long route from the lumbar to the pelvic region, experiences many anomalies and changes. Note the long ureteral spindles at 4 and 6, XXVII (woman).

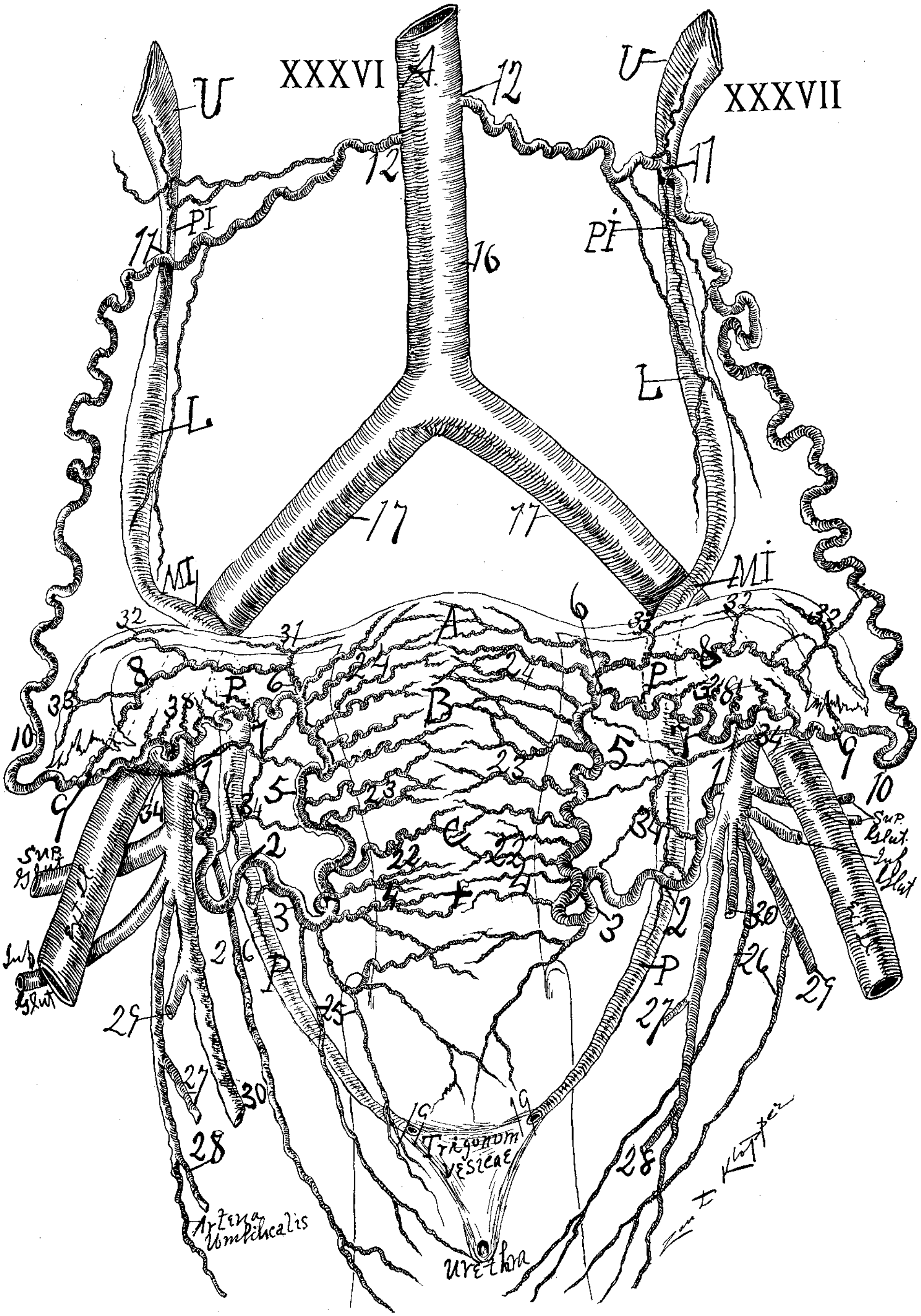

FIG. 7 is a cut produced by dissection under alcohol after an X-ray had been taken. Subject about forty-five years. Ureteral spindles and isthmuses distinct and in usual location. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, spiral segment of the utero-ovarian or genital vascular circle. The important proximal (11) and distal (2) arterio-ureteral as well as the cervical loop (2, 3, 4).

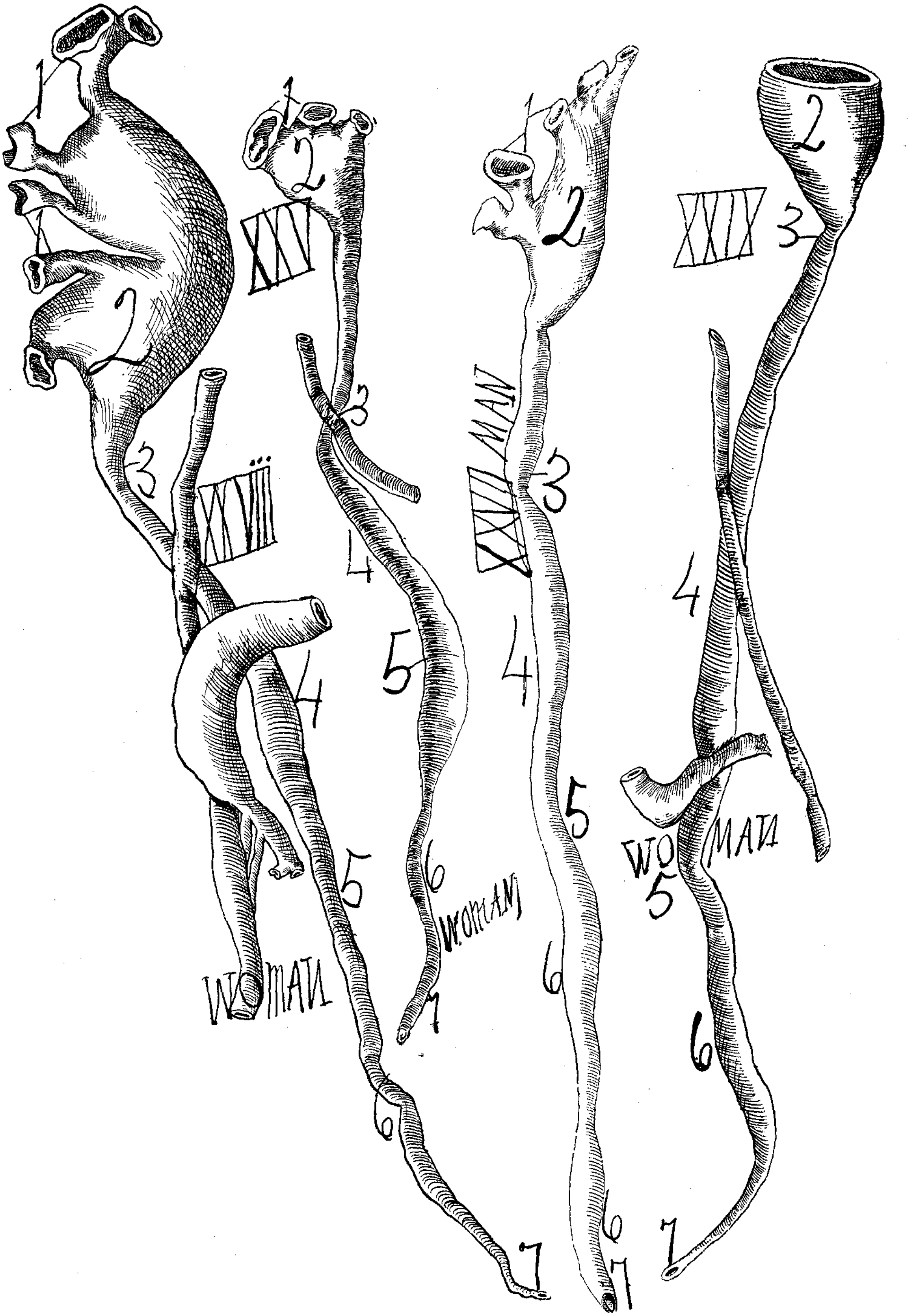

FIG. 8.—XXVIII and XXIX from the same female subject in natural course. The peculiar shaped calices and pelvis attract attention. Note the arterial ovarian segment, especially the large venous ovarian segment on No. XXVIII at 4. No. XXV, a woman, shows pronounced spindles and isthmuses. 3. Proximal arterio-ureteral crossings. No. XXVII, a man, shows two pelvic spindles.

The dimensions of the ureter are variable. The length lying in the body *in situ* is shorter than it is extirpated and extended. The diameters and locations of the ureteral isthmus or sphincters vary within wide ranges. The capacity and locations of the ureteral reservoirs vary within an extensive zone.

Matrix. (Tissue bed.)—1. The ureter lies in a universally loose areolar and fascial bed. 2. It is located immediately extraperitoneal and is loosely attached to it by fibres. 3. The ureteral bed allows not only the constant periodic rhythmical wave or peristalsis of the ureter, but wide range of motion without trauma or altering its integrity. 4. The bed of the pars lumbalis is the ventral surface of the psoas muscle, which doubtless aids ureteral peristalsis by its contraction and relaxation. 5. The bed of the pars iliaca is the vasa iliaca whose contraction and dilatation (rhythm) also aids ureteral rhythm. 6. The pars pelvina has a more fixed bed with less rhythmic adjacent organs. 7. The loose yielding ureteral bed allows the ureter to be drawn extensively from its bed for surgical intervention or to be forced from its bed by pathologic processes. The pars vesicalis is the most mobile segment.

Position.—The position of the ureter should be considered in relation to (*a*) the general body, (*b*) in relation to the osseous skeleton, (*c*) in relation to adjacent structures, and (*d*) in relation to its component segments.

I. *Holotopy.* (Relation to the general body.)—1. The ureters lie bilaterally extraperitoneal on the dorsal lumbar and lateral pelvic wall. 2. They lie half in the abdominal, half in the pelvic cavities. 3. They are the most securely protected ducts in the body. 4. The pars renalis is extensively mobile; the pars lumbalis is quite mobile as well as the pars iliaca; the pars parietalis pelvina is quite fixed, while the pars vesicalis is extensively mobile. 5. The left ureter is nearer the median line than the right. 6. Practically the ureter extends from the twelfth rib to the pelvic floor.

II. *Skeletopy.* (Relation to osseous skeleton.)—1. They lie (*a*) bilaterally ventral to the II, III, IV, and V lumbar transverse processes; (*b*) on the sacro-iliac joint, and (*c*) along the lesser lateral pelvic wall. 2. The middle of the ureter corresponds to the mid-point of a line drawn from the processus xiphoideus to the crest of the symphysis pubis. 3. The course of the ureter corresponds practically to a line extending perpendicularly from the junctions of the inner and middle thirds of the ligamentum inguinale (Poupart's) to the twelfth rib. The left ureter lies slightly nearer the vertebral column than the right. 4. The flexura iliaca ureteris, *i.e.,* where the ureter crosses the vasa iliaca, is a short distance proximal to the horizontal plane of the anterior superior spines of the ilium. 5. The middle arterio-ureteral crossing, *i.e.*, the point where the ureter crosses the vasa iliaca, corresponds to the sacro-iliac joint, is the nearest to the anterior abdominal wall. 6. At the sacral promontorium the ureters are two and one-half to three inches apart. 7. In the lesser pelvis the ureter courses close to the base of the spina ischiadica.

III. *Syntopy.* (Relation to adjacent organs.)—General. The ureter lies in an extensive mobile bed of loose areolar and fascial tissue. 1. It is located immediately dorsal to the peritoneum, surrounded by a fibrous areolar sheath, and is attached to the peritoneum by a certain number of fibrous strands which rupture on separating the ureter and peritoneum. In spare subjects one can observe the ureter resembling a white band shimmering through the dorsal peritoneum. The ureter lies immediately dorsal to the peritoneum, being loosely attached to it.

A. (Ventral.) 2. *The blood-vessels* ventral to the ureter are: (*a*) The vasa ovarica which cross the ureter at the proximal arterio-ureteral crossing of the utero-ovarian artery (lumbar region). (*b*) The vasa uterina which cross the ureter at the distal arterio-ureteral crossing of the utero-ovarian artery. This is the most important landmark in the pelvis. It is the grand pelvic crossing. It is a fixum punctum. (*c*) (Right.) The vasa ileo colica and vasa colica media dextra (mesenterica superior). (*d*) (Left.) Vasa colica sinistra (mesenterica inferior). In the pars lumbalis ureteris all vessels pass ventral to the ureter and immediately under the peritoneum; hence the ureter can be surgically attacked retroperitoneally without damage to visceral vessels. Surgical attacks on the pars pelvina ureteris are dangerous as regards vessels. The nervosa plexus ovarica passes ventral to lumbar ureter. The *organs* ventral to the ureter (right) are: (*a*) peritoneum duodenum; (*b*) distal end of ileum (with perhaps cæcum and appendix); (*c*) ovarium; (*d*) oviduct; (*e*) ligamentum latum; (*f*) urinary bladder. (Left.) (*a*) Sigmoid (the ureter lies in the fossa intersigmoidea); (*b*) ovarium; (*c*) oviduct; (*d*) ligamentum latum; (*e*) urinary bladder; (*f*) enteronic loops lie ventral to both right and left abdominal ureter.

B. (Dorsal.) 1. The ureter lies extensively on a *muscular* bed. (*a*) The most extensive muscular support of the ureter is furnished by the psoas muscle (major and minor), on which it loosely lies from its origin to the vasa iliaca; (*b*) the ureter is less intimately related to pyriformis; (*c*) obturator internus; and (*d*) levator ani. The pelvic muscles are divided from the ureter by the branches of the internal iliac with their tunic fibrosa vascularis and the plexus nervosus sacralis. The muscularis rotundum uteri has distant relations with the ureter.

2. *Blood-vessels* dorsal to the ureter are: (*a*) The vasa iliaca which project the ureter into an angle, the flexura iliaca ureteris; (*b*) branches of the internal iliac; (*c*) the ureter courses through a vast mesh-work of pelvic veins (plexus pampiniformis). 3. *The nerves* dorsal to the ureter are: (*a*) Lumbar lateral chain; (*b*) lumbar plexus, both embedded in the psoas muscle; (*c*) the nervus genito femoralis lies dorsally almost in contact with the ureter; (*d*) the hypogastric plexus; (*e*) plexus nervosus sacralis.

C. (Lateral.) 1. *The viscera* external to the ureter are: (*a*) The distal pole of the kidney. The portio adrenalis ureteris lies close and fixed to the kidney, mainly lying in a groove in the renal substance. It is enclosed in the adiposus renalis; (*b*) the right colon lies at some distance external to the ureter; (*c*) the appendix and cæcum are mainly externally lateral to the ureter. The left colon is further removed laterally from the ureter than the right colon. 2. The *muscles* lying laterally to the ureter are: (*a*) Psoas; (*b*) pyriformis; (*c*) obturator internus, and (*d*) levator ani.

3. *Blood-vessels* lying laterally are: (*a*) The middle of the vasa ovarica, lying parallel to the ureter; (*b*) the vasa iliac externis; (*c*) branches of the vasa iliac internus. 4. *The nerves* lying lateral are: (*a*) the middle segment of the plexus ovarica; (*b*) plexus lumbalis; (*c*) plexus sacralis.

D. (Medial.) 1. The blood-vessels lying medialward from the ureter (right) are (*a*) a segment of the vasa ovarica; (*b*) the vena cava to which the ureter lies close, frequently in contact; (*c*) the uterine segment of the utero-ovarian artery lies close to the pelvic segment of the ureter.

(Left.) The left ureter lies nearer the aorta than the right. The ureter at the important medial arterio-ureteral crossing, *ie.*, at the point where the ureter crosses the vasa iliaca, reverses its intimate medial relations to large vessels, and assumes externally lateral relations to the large vessels. 2. Medially the ureter is related to *nerves,* (*a*) the lateral lumbar chain; (*b*) the hypogastric plexus; (*c*) the cervico-uterine ganglion (pelvic brain). 3. The medial *visceral* relations of the ureter are (*a*) the rectum, which the ureter quickly approaches on entering the lesser pelvis.

At the pelvic floor the ureter and rectum approach still closer, whence the rectum becomes directed dorsally and the ureter ventrally. High rectal operations involve the ureters. Distended rectum closely approaches the ureters. (*b*) The ureter approaches the lateral surfaces of the bladder from its fundus or dorsal wall. It passes to the bladder through the large plexus venosus vesicalis, whence it penetrates the bladder-wall obliquely for about three-quarters of an inch to end as a mucous slit, the distal orificium ureteris. In penetrating the vesical wall obliquely it forms a valve which prevents regurgitation of urine. The ureter does not blend with the vesical muscularis, but passes through the bladder-wall independently, accompanied by its tunica fibrosa. (*c*) The ureter courses about one-half inch from the lateral border of the cervix immediately dorsal to the arteria uterina. (*d*) The ureter passes through the vast plexus venosus vaginalis to the lateral and

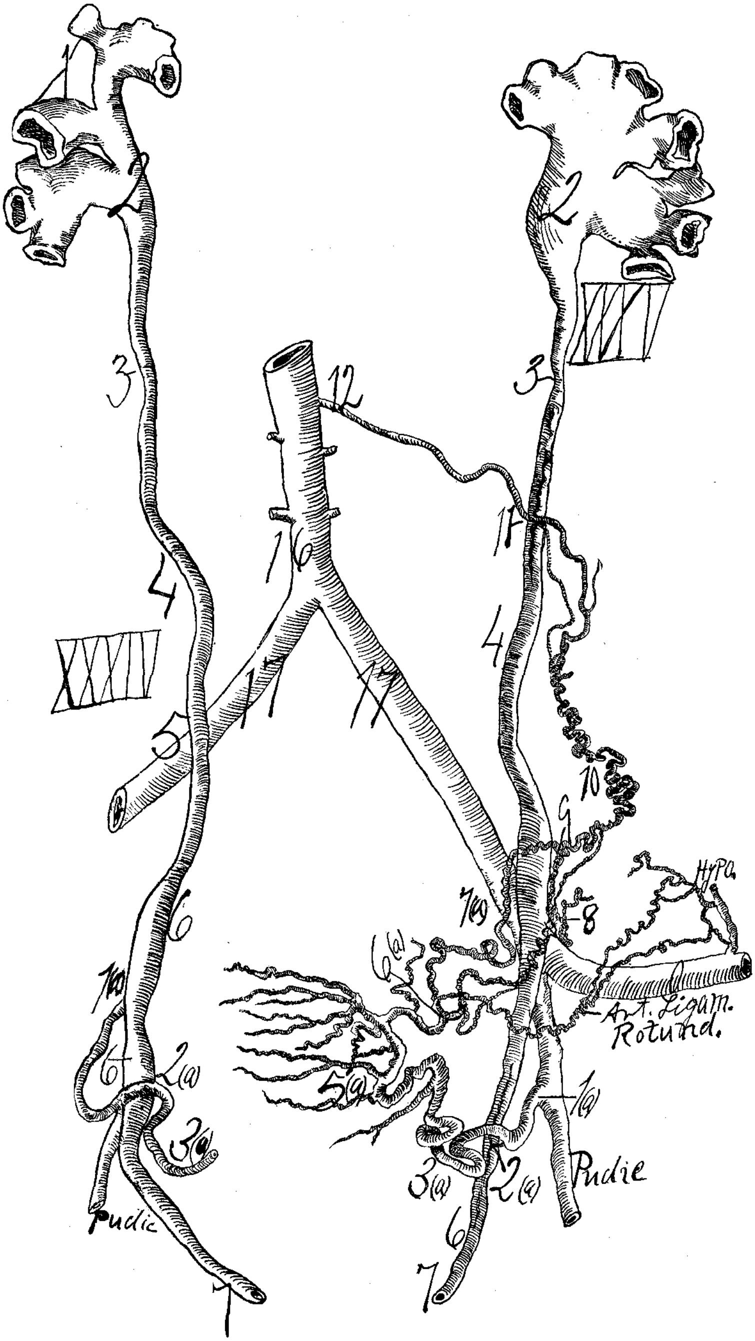

FIG. 9 presents the ureters in relation to the utero-ovarian vascular circle, especially in No. XXXV. The spiral segment of the utero-ovarian vascular circle—circle of author—(1 (a), 2 (a), 3 (a), 4 (a), 5 (a), 6 (a), 7 (a), 8, 9, 10, 11, 12) is a tripedal arch with one foot arising from the aorta (12); another foot springs from the internal iliac at 1 (a), and a third foot is emitted from the external iliac (hypo). The spiral segment crosses ventral to the ureter three times, but presents practical relations with the ureter only at the proximal (11) and distal (1 (a)) arterio-ureteral crossings. The most important of all arterio-ureteral relations is the distal arterio-ureteral crossing at 2 (a), and also the ureteral relations to the cervical loop (2 (a), 3 (a), 4 (a)).

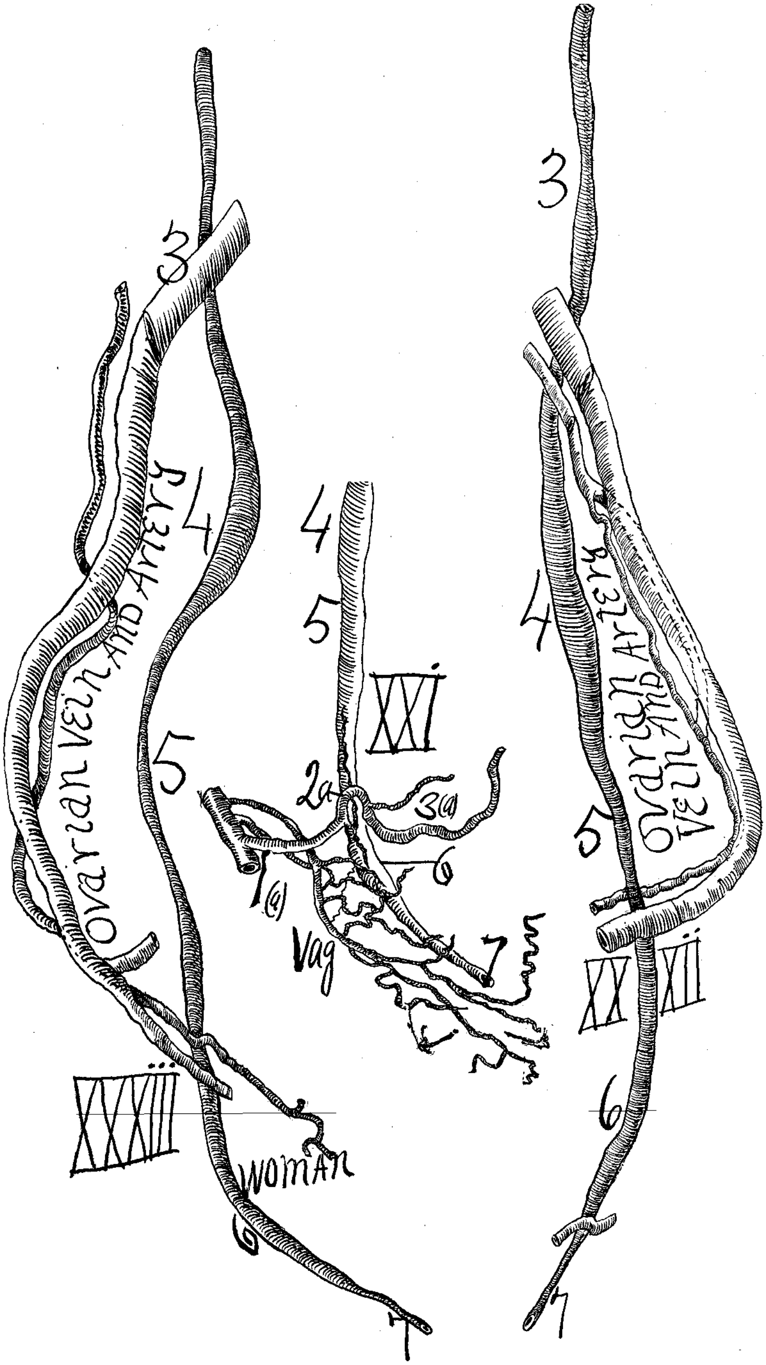

FIG. 10.—Nos. XXXII and XXXIII, middle-aged woman with prominent ureteral spindles. XXXIII has three pelvic ureteral spindles. XXI, distal end of female ureter with relations to arteria uterina (1 (a), 2 (a), 3 (a)) and arteriæ vaginales (Vag.), two spindles (4) and (6) pronounced.

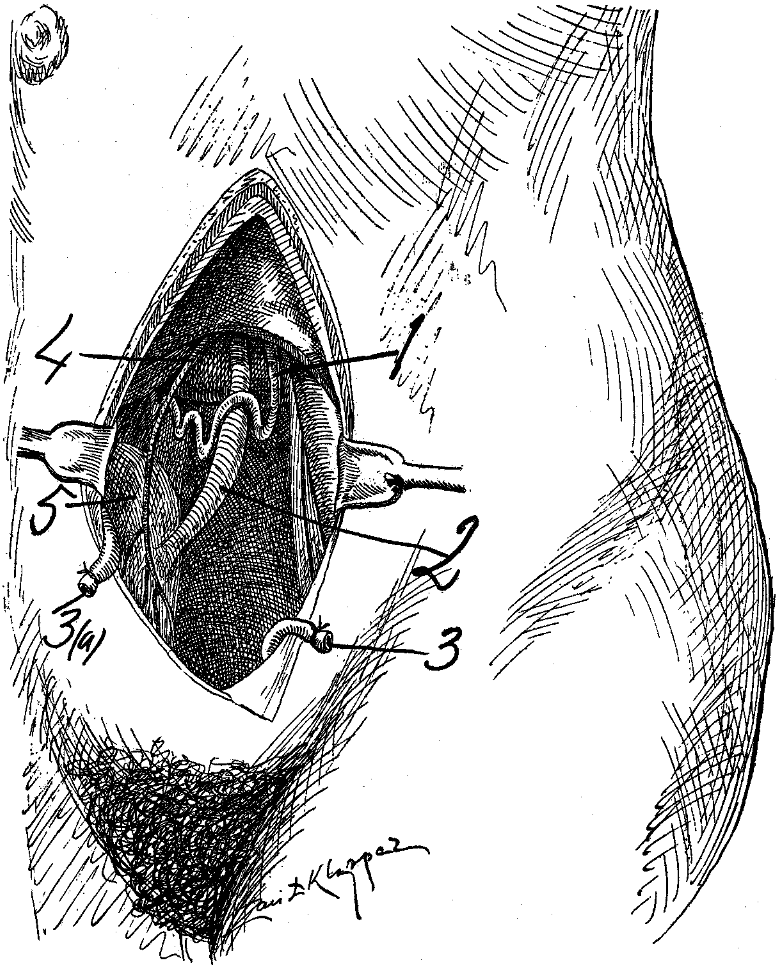

FIG. 11.—Ureter in erect attitude exposed. 1. Arteria uterina with its arterio-ureteral crossing on the ureter and the cervical loop between the uterus and ureter. 2. Pelvic ureteral spindles. 3 and 3 (a). Arteria hypogastrica. 4. Arteria vesicals superior. 5. Vesica urinaria. In this drawing a suggestion from Drs. Tandler and Halban is employed.

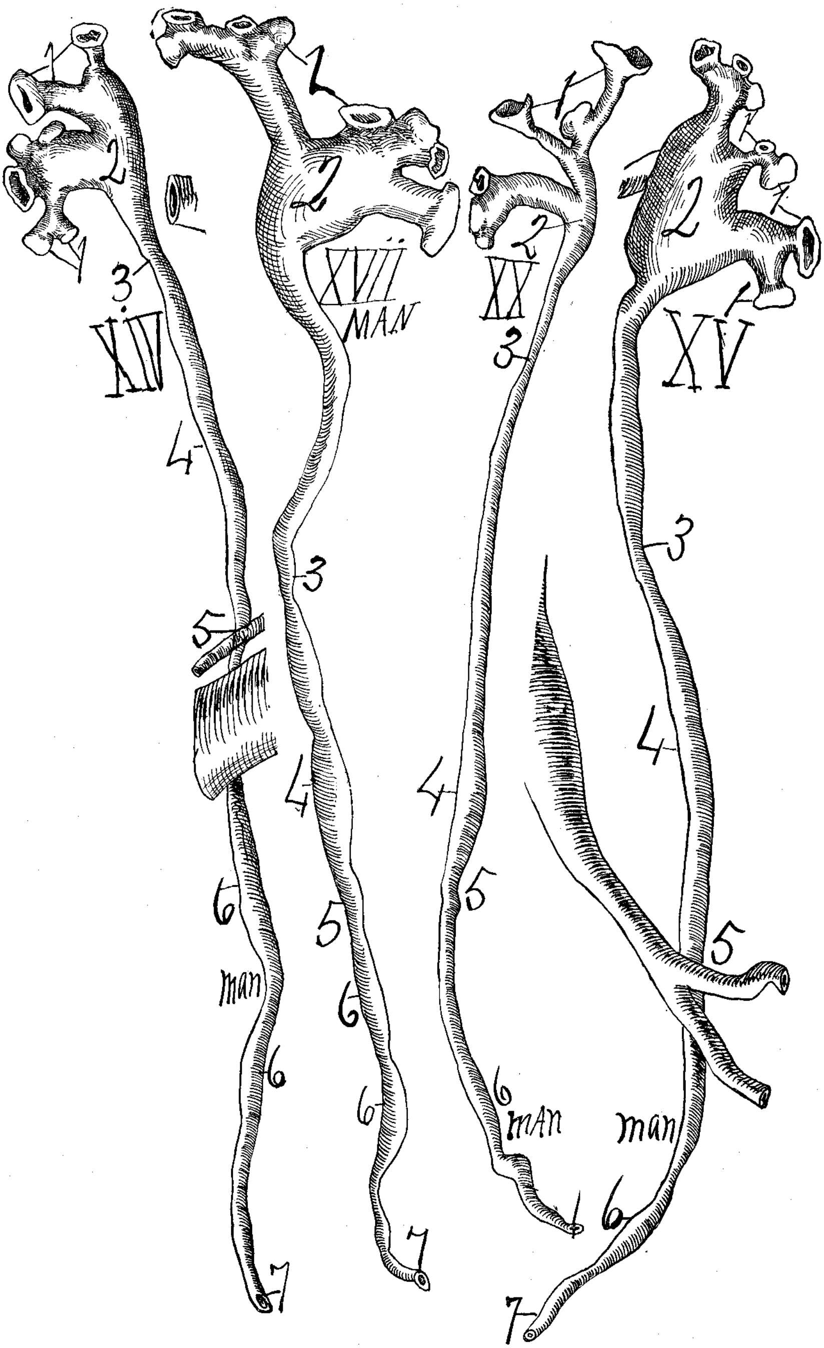

FIG. 12.—Nos. XIV and XV are from the same male subject with ureters in natural course. The common iliacs at 5 (No. XV) did not fill with injected mass, hence small. At 5 (No. XIV) the common iliac filled, hence natural size.

(P.S.—The ureters XIV and XV, by mistake, were drawn dorsal to the arteriæ iliaca.)

Observe the pronounced spindles in No. XVII; both the lumbar (4) and pelvic spindles (6, 6) appear double. Note variations in calices and pelvis.

ventral vaginal fornices, where it assumes important relations with the vagina, especially in pelvic surgery; the trigonum vesicæ rests on the ventral vaginal wall.

IV. *Idiotopy.* (Relation of component ureteral segments.)—The important factors in the relations of the different component segments of the ureter to each other are the narrow isthmuses, the wide reservoirs, the calices, and the ureteral flexures. Ureteral isthmuses obstruct calculi, while spacious ureteral reservoirs entertain them. Ureteral flexures may obstruct both urine and calculi.

Development.—The ureter arises from an invagination of the mesonephrotic duct located at the end of the Wolffian body. It is the duct of the matanephros.

Number.—Two, bilaterally symmetrical.

Form.—1. It is irregularly cylindrical in the living, depending on quiescence or function. In cadaver it is flattened from pressure chiefly dorsoventral. 2. It is an irregular calibered tube. 3. It has usually three dilatations (ureteral reservoirs). 4. Its calices are irregular in number, size, and distribution. 5. Its reservoirs, ureteral pelvis, lumbar and pelvic spindle are irregular in size and location, and the spindles vary in number. 6. Its isthmuses or sphincters are irregular in location and caliber and number.

7. Curvatura ureteris.
    1. Medial lumbar.
    2. Lateral pelvic.
    3. Ventral lumbar.
    4. Dorsal pelvic.
    5. The curves of the ureter resembling the letter S imitate the body wall.
8. Planum ureteris.
    1. Dorsoventral. (Lumbosacral curves due to osseous skeleton.)
    2. Transverse. (Lumbopelvic curves due to distal kidney pole and expansion of lateral pelvic wall.)

9. The rule of late developed organs, as the ureter, is to be subject to frequent anomalies of form and irregular caliber.

Borders and Surfaces are exposed in detail in discussion on ureteral position and ureteral relations to adjacent individual structures.

Sphincters.—There are three important sphincters or isthmuses: 1. A proximal isthmus or sphincter located at the so-called neck of the ureter. This bend or kink is due to the medial projection of the distal kidney pole. This ureteral curve I shall term the flexura renis ureteris.

2. There is a middle ureteral sphincter or isthmus located at the middle arterio-ureteral crossing, *i.e.,* where the ureter crosses the vasa iliaca. This ureteral constriction is due to the ventral projection of the ureter by the iliac vessels. This bend or kink in the ureter I shall term the flexura iliaca ureteris. It is the most accessible to palpation.

3. There is the distal ureteral sphincter or isthmus located at the point where the ureter penetrates the bladder-wall. This sphincter is due to the gradual narrowing of the ureteral caliber as it passes obliquely through the muscularis and mucosa of the parietes vesica urinaria.

The diameters of the three ureteral sphincters or isthmuses in order of dimensions are: 1. The distal, one-tenth of an inch; 2. Proximal, one-seventh of an inch, and 3. The middle, one-fourth of an inch.

Flexures.—There are three important flexures. 1. The flexura renis ureteris, located at the ureteral neck and due to the medialward projection of the distal kidney pole. 2. Flexura iliaca ureteris, *i.e.,* where the ureter is flexed as it crosses the vasa iliaca. 3. Flexura pelvina ureteris, *i.e.,* where the ureter lies curved on the bladder and pelvis wall.

Proximal Extremity.—The proximal extremity consists of the ureteral calices and ureteral pelvis located in the renal sinus or renal pocket.

1. It begins at the renal pyramids which project, or invaginate, into the ureteral calices like a finger in a glove. 2. As a rule, each renal pyramid opens sieve-like into a ureteral calyx.

3. The proximal end of the ureter presents from four to eighteen, usually, however, about eight calices. 4. The junction between ureteral calyx and renal substance, pyramid, is at the sieve-like perforated apex of the renal pyramid. 5. The blunt rim of the ureteral calyx surrounds the base of the renal pyramid. 6. A major ureteral calyx is a varying cylindrical structure of about one inch in length and one-third of an inch in diameter, which opens distalward at its apex by sieve-like openings. 7. The ureteral calices, the beginning of the ureter, are attached to the floor of the renal pocket by means of renal pyramids perforated at their apices. 8. The ureteral calices consist of a proximal set which converge into a main proximal arm and a distal set which unite into a main distal arm; finally, the main proximal and distal arms of the calices open into the ureteral pelvis. 9. Practically, each kidney consists of a collection of varying sized kidneys—the renal pyramids—which pour their urine into separate calices, and the calices pour their contents into a common reservoir,—the ureteral pelvis. 10. The calyx presents the shortest distance and most direct route from the renal pyramid to the ureteral pelvis. 11. The calices, like the tributary arms of a great river, collect the urine from the various renal regions drained by the pyramids and converging streams into the great urinal reservoir—the ureteral pelvis, which, with the calices, will frequently hold an ounce. 12. The proximal ureteral extremity rests in a rich bed of areolar fascial tissue which may become so extensive that it appears pathologic. The connective tissue compactly surrounds the proximal extremity of the ureter so strongly that it makes a difficult dissection to free it for inspection. 13. The proximal calicular arm is the chief one as regards direction, but is the smaller. 14. The distal calicular arm is the larger, and contains perhaps one or two more calices, but appears more like lateral tributaries to the ureteral pelvis. 15. The caliber of the ureteral pelvis, irregularly oval, is about four times that of the calices.

The ureteral pelvis (right) lies dorsal to the junction of the duodenum descendens and duodenum transvenum, while the left ureteral pelvis lies close to the junction of the colon transversum and sinistra; both these relations of position are variable.

Distal Extremity. — 1. It penetrates the bladder-wall obliquely for about three-fourths of an inch.

2. It forms within the bladder-walls a perfect non-regurgitating valve.

3. It opens significantly in the vesical mucosa as a depressed oblique, oval, mucous slit one-eighth of an inch in length. Urine may enter a distended bladder, but it cannot escape by regurgitation, on account of the oblique valve in the vesical wall.

4. The ureteral orifices form two of the angles of the trigonum vesicæ (Lieuataudii), and are located with the chief sensory nerves in the foldless mucosa of the trigone.

5. The distal end of the ureter penetrates the tunica fibrosa and tunica muscularis of the bladder independently surrounded by (a ureteral sheath) musculo-fibrous tunic. The ureteral orifice necessarily blends with the vesical mucosa.

6. The independent penetrations of the bladder-wall by the ureter surrounded by its own ureteral sheath or musculo-fibrous tunic insures independent bladder and ureteral function.

7. The distal ureteral orifices stand about one inch apart in the resting bladder, but in the well-distended bladder they may be separated two inches.

8. At the proximal external angle of the mucous oval slit of the distal ureteral orifice there is a thin mucal fold which facilitates ureteral catheterization. Immediately after the ureter enters the pelvis, it becomes richly supplied by a large number of veins, and the nearer it approaches the tractus genitalis the more it resembles it in being supplied by a large number of large veins. The distal end is the most mobile of the ureteral segments; however, it moves with the trigonum vesicæ and the enclosed musculo-fibrous ureteral sheath. Perhaps the space between the ureter and ureteral sheath is a space which facilitates the wide range of mobility of the distal ureter.

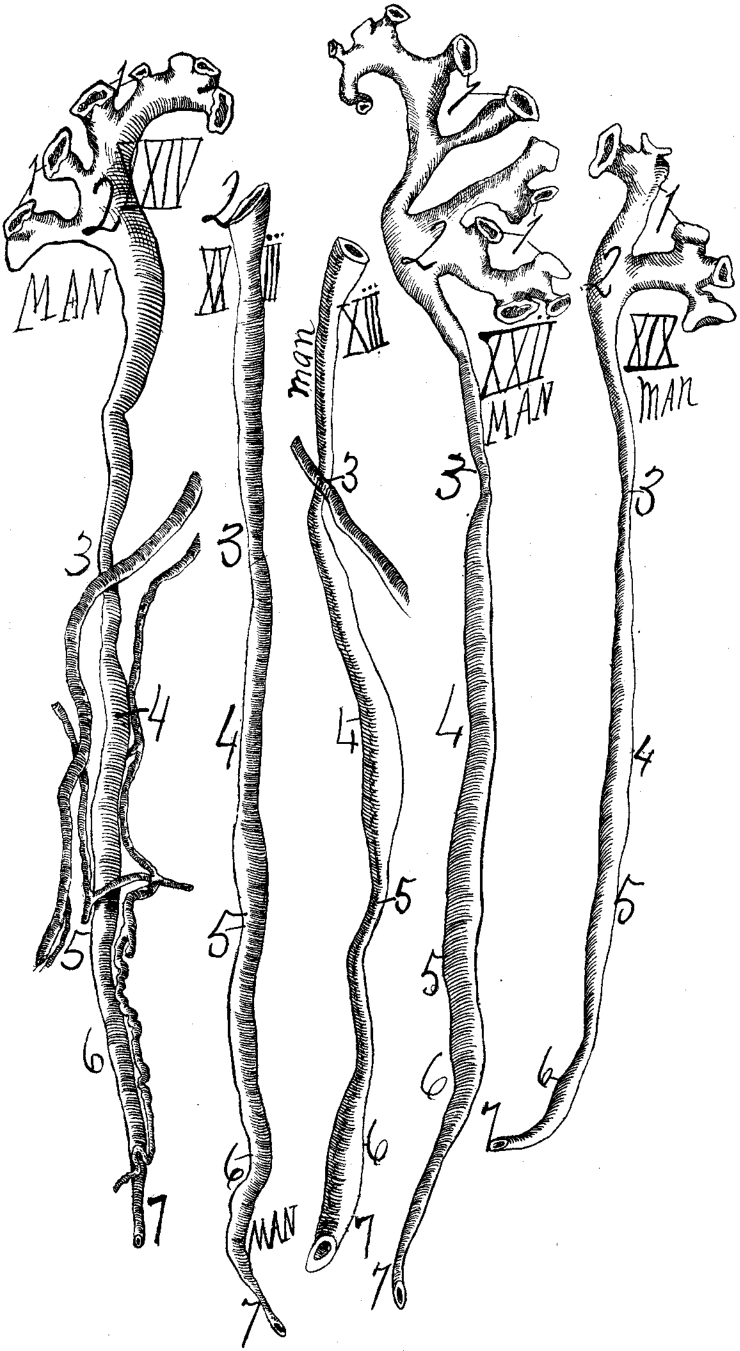

FIG. 13 presents a wide range of ureteral calices, pelves, isthmuses, and spindles. The calices vary more than any other ureteral segment. The calices consist practically of a major, proximal arm, and a major, distal arm. No. XXIV is accompanied by the injected spermatic vessels.

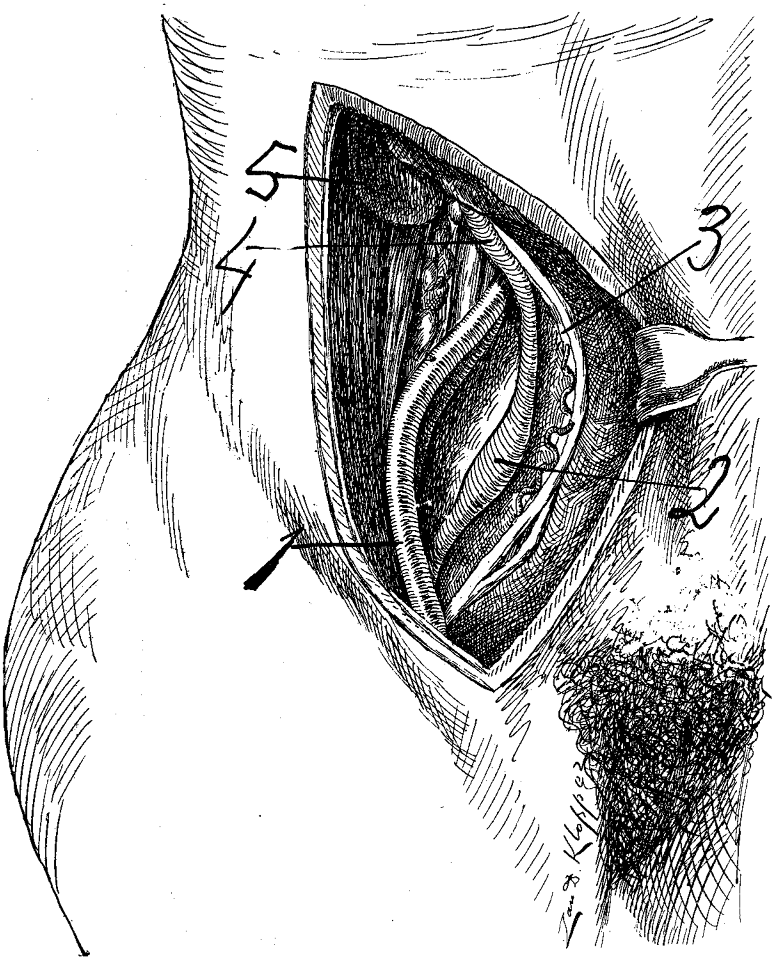

Fig. 14 presents the lumbar ureteral spindle exposed in the lateral abdominal region while in the erect attitude. 1. Arteria iliaca communis. 2. Lumbar ureteral spindle. 3. Vasa spermatica. 4. Pars infrarenalis ureteris. 5. Kidney. In this cut a suggestion from Drs. Tandler and Halban is used.

The Relation of the Ureter to Other Viscera and Adjacent Structures.—Relation of the ureter to vessels is of practical importance. The most important uretero-vesicular relation is (*a*) the distal arterio-ureteral crossing of the pelvic-floor segment of the utero-ovarian artery. This is the most important landmark in the pelvis. It is generally located about the midpoint of the pelvic-floor segment. It is also located about midway between the lateral cervical border and lateral pelvic wall. The distal arterio-ureteral crossing is the point where the ureter crosses dorsally at acute angle the arteria uterina. It is the grand pelvic crossing (Lucy Waite). It is the pelvic arterio-ureteral fixum punctum where the T-shaped distal arteria ureterica is emitted which passes both proximal and distalward on the ureter.

(*b*) The middle arterio-ureteral crossing is where the ureter crosses the vasa iliaca ventrally, also where the middle arterio ureterica passes from the arteria iliaca to the ureter. This is a practical point, as the ureter here approches the closest to the ventral abdominal wall, and may be palpable.

(*c*) The proximal arterio-ureteral crossing is where the ureter passes dorsal to the ovarian segment of the utero-ovarian artery, and where the T-shaped arteria ureterica is emitted, passing proximal and distalward on the ureter. The proximal uretero-ureteral crossings, usually not on the same level, are located at the apex of the uretero-venous triangles of the author. The arteries ileocolic, colica dextra, and those of the inferior mesenteric artery (sinistra) pass ventral to the ureter.

As to veins, the right ureter lies close to the distal vena cava, while the pelvic ureters pass through vast plexuses of large veins. The relation of the ureter to great venous plexuses may be observed in its course through (*a*) the plexus venosus uretero-vaginalis, and (*b*) the plexus venosus vesico-vaginalis. The extra musculo-fibrous tunic ureteral sheath of the distal end is microscopically rich in vessels, and firmly bound to the distal arterio-ureteral crossing as well as some of the arteriæ vaginales which supply its distal ureteral end. The left ureter lies close to the abdominal aorta.

The relation of ureter to the vagina is of extreme practical importance in gynæcology and obstetrics. Immediately after the ureter has passed the cervix uteri it lies embedded in a loose mass of cervico-vesical connective tissue between vagina and fundus of the bladder. The ureter lies practically in contact with the lateral and ventral vaginal fornices for about one-half of an inch. The ureter in its vaginal relations is well sheathed by the extra tunica musculo-fibrosa ureteral sheath. From a point about two-thirds of an inch distant from each lateral border of the cervix uteri the ureters converge medially. If one looks dorsalward into a well-dissected pelvis, the two medially converging ureters appear to embrace the proximal end of the vagina like two lateral arms. The ureter and vaginal wall are in contact at about the level of the ventral cervical lip, the most distal point of the cervix. Since the ureter is in fixed contact with the ventral vaginal wall through strong connective tissue, it moves with the proximal vagina; hence, in performing vaginal hysterectomy the cervix should be drawn well distalward, and the ventral vaginal wall forced well proximalward by instruments during separation of bladder from uterus, to avoid injuring the ureters. The distal ureteral orifices correspond to a point at the level of the middle of the vagina. The ureteral orifices lie about one and one-half inches distal to the os uteri externum.

The extra fibro-muscular ureteral sheath extending several inches at the distal end of the ureter guards the ureter from injury. It is by means of the fibro-muscular ureteral sheath that it is so intimately connected with blood-vessels, vagina, and bladder.

Relation of the Ureter to the Bladder.—The relation of the ureter to the bladder should be considered in two segments, viz., (*a*) extramuralis and (*b*) intramuralis. Both extra- and intra-vesical segments are of extreme importance in obstetrics and gynæcology, especially in the large field of vaginal hysterectomy. The extra-mural segment is the one which is the

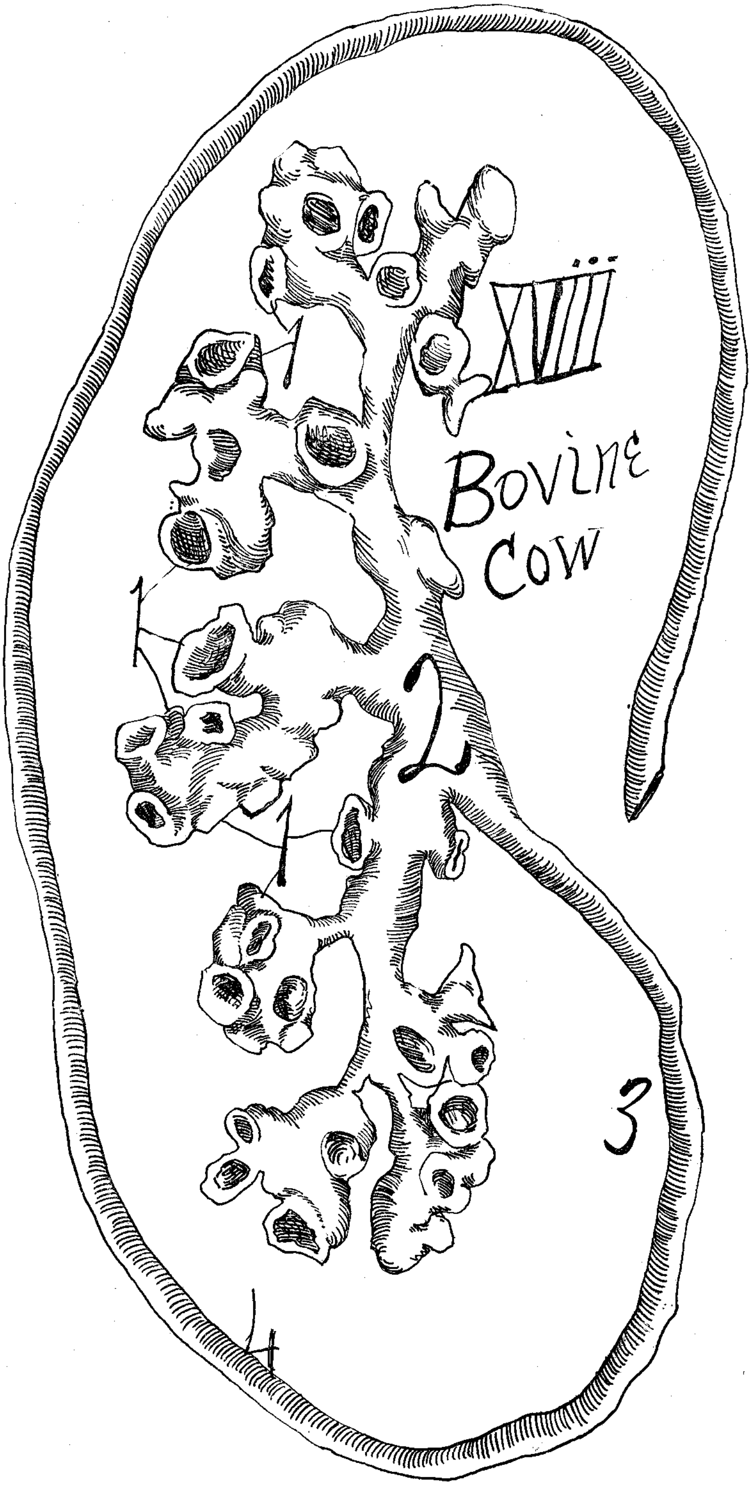

FIG. 15.—Adult cow's ureter. 1. 1. 1. Calices. 2. Pelvis. 3. and 4. Ureter proper. Animals possessing lobulated kidneys possess numerous branched calicular arms with insignificant ureteral pelvis. Animals with smooth kidneys possess a ureteral pelvis. This ureter (quadruped) has spindles. It is not a uniform calibered duct. The irregular appearances are due to the injection to a slight extent.

more liable to trauma on account of its intimate relation to the cervical loop or the internal position of the pelvic-floor segment of the utero-ovarian artery. The extra-mural portion is also the segment of the ureter which is so intimately related to the vagina. The extra-mural segment possesses a strong ureteral sheath which accompanies the ureter through the bladder-wall. It bends medialward before it ends in the bladder. The pars intramuralis is the half inch of the fixed distal end of the ureter. It lies within the vesical wall. The ureteral sheath lessens as the ureter passes with it obliquely through the bladder-wall. The distal ends of the two ureters and the proximal end of the urethra together form the trigonum vesicæ and isosceles triangle of foldless mucosa containing the chief vesical sensory nerves. A ureteral fistula in either the intra-mural or extra-mural segments is difficult to heal. I have observed one in practice that lasted three years in spite of numerous operations. The extra-mural segments in the resting bladder are separated about one and one-half inches, but in a well-filled bladder may be separated over two inches.

Relation to the Cervix.—The relation of the ureter to the cervix uteri is important in gynæcology and obstetrics, especially in hysterectomy per vaginam. The ureter passes by the lateral border of the cervix uteri about two-thirds of an inch distant from its supravaginal portion. Its course is acutely oblique as regards its cervix uteri.

From the distal arterio-ureteral crossing the ureter rapidly approaches the border of the cervix uteri. The ureter lies between the cervicovaginal venous plexuses. As it courses by the cervix, it lies in a vast bed of loose areolar tissue, and is hence mobile and shiftable, changing its distance from the cervix uteri. One can force the ureter not only the length of the cervical loop, which may be one and one-half inches from the cervical border, but over half an inch additional. This allows two inches of cervical loop to ligate in hysterectomy, which is utilized through drawing the cervix distalward by traction forceps. Through the distal arterio-ureteral crossing, the grand crossing of the pelvis, is a fixum punctum due to the distal arteria ureterica being emitted at this point by the strong connective tissue, yet this fixum punctum can be shifted, forced laterally, which is the all-important point in gynæcological surgery, gaining space in order that ureteral trauma may be avoided. Practically, the ureters embrace the cervix uteri at the level of its internal os, viz., about one and one-half inches previous to penetrating the vesical wall. At the level of the internal os the ureters are separated about two and one-half inches; however, by traction forceps on the cervix this distance can be materially changed. Successful avoidance of

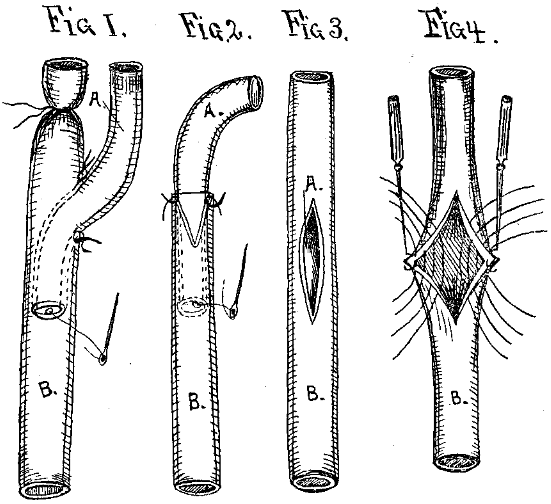

FIG. 16 illustrates methods of ureteral repair. A. Proximal and (B) distal segment of ureter. Fig. 1. A is drawn into the lumen of B through a slit in the lateral ureteral wall and sutured *in situ.* B is ligated at its proximal end. Fig. 2. A is drawn into the lumen of B through the proximal end of B, which is facilitated by splitting the proximal of B. It is sutured *in situ.* Fig. 3 may present a stricture of the ureter, to relieve which an incision is made longitudinal to the ureter; subsequently the ureteral incision is sutured transversely as is indicated in Fig. 4. Dr. Van Hook's method is included in this cut. It is very evident that ureteral surgery is facilitated by performing the operation in the region of the spindles or reservoirs, where ample lumen and wall present for manipulation and suture.

ureteral trauma consists in two factors, viz., drawing the cervix distalward with traction forceps and forcing the ureters lateralward and proximalward with specula.

Relation of Ureter to Rectum is important in Practice.—
1. The ureter varies in its relation to the rectum according to the resting (contracted) or distended (functionating) state of the rectum.

2. The ureter assumes intimate relations with the rectum immediately on entering the lesser pelvis.

3. The ureter and rectum assume the same sagittal sacral curve with concavity ventrally.

4. The left ureter is about one inch distant from the rectum in the proximal part of the lesser pelvis, while the right ureter is about one and one-half inches.

5. In the distal segment of the lesser pelvis the ureter reapproaches the middle line, while the rectum becomes diverted dorsally.

6. The distended rectum presses against the ureters.

7. The most important point of the relations of the ureter to the rectum is found at (*a*) the level of the spina ischiadica, (*b*) the spina ischiadica corresponds to the ligamentum sacro-uterina, (*c*) the spina ischiadica corresponds to the point where the ureters curve medialward to pass to the bladder, (*d*) the spina ischiadica corresponds to the level of the sphincter vesicæ interna.

At the spina ischiadica the ureter and rectum approach the closest to each other.

8. In extensive operations on the rectum, as the Kraske, the ureters are in danger of trauma. They should be forced with their ureteral sheath from the operative field by traction forceps or specula.

At the pelvic brim the ureters lie against the vertebral column ventral to the transverse processes, and on the ala sacra separated about two and one-half inches, with a segment of the rectum lying between them. Here they approach close to the sigmoid depending on the length of the mesosigmoid, whence they diverge to follow the lateral pelvic wall, gaining a maxi-

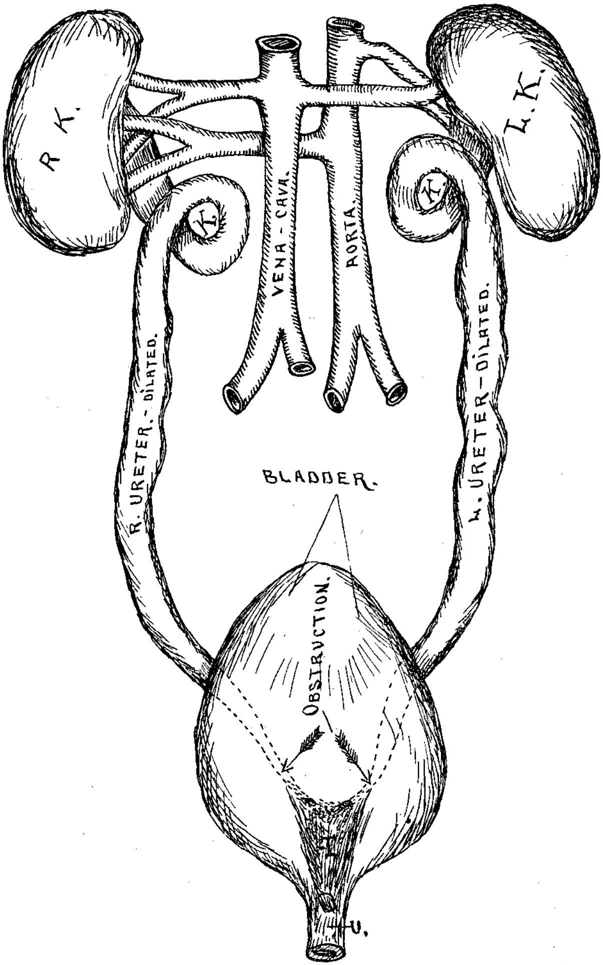

FIG. 17.—Cut demonstrating extensive bilateral ureteral dilatation due to obstruction in the pars intramuralis ureteris. The ureters were extended almost to the size of the enteron. I secured this rare specimen at an autopsy and sketched it *in situ.* Observe the large ureteral spiral at K, K.

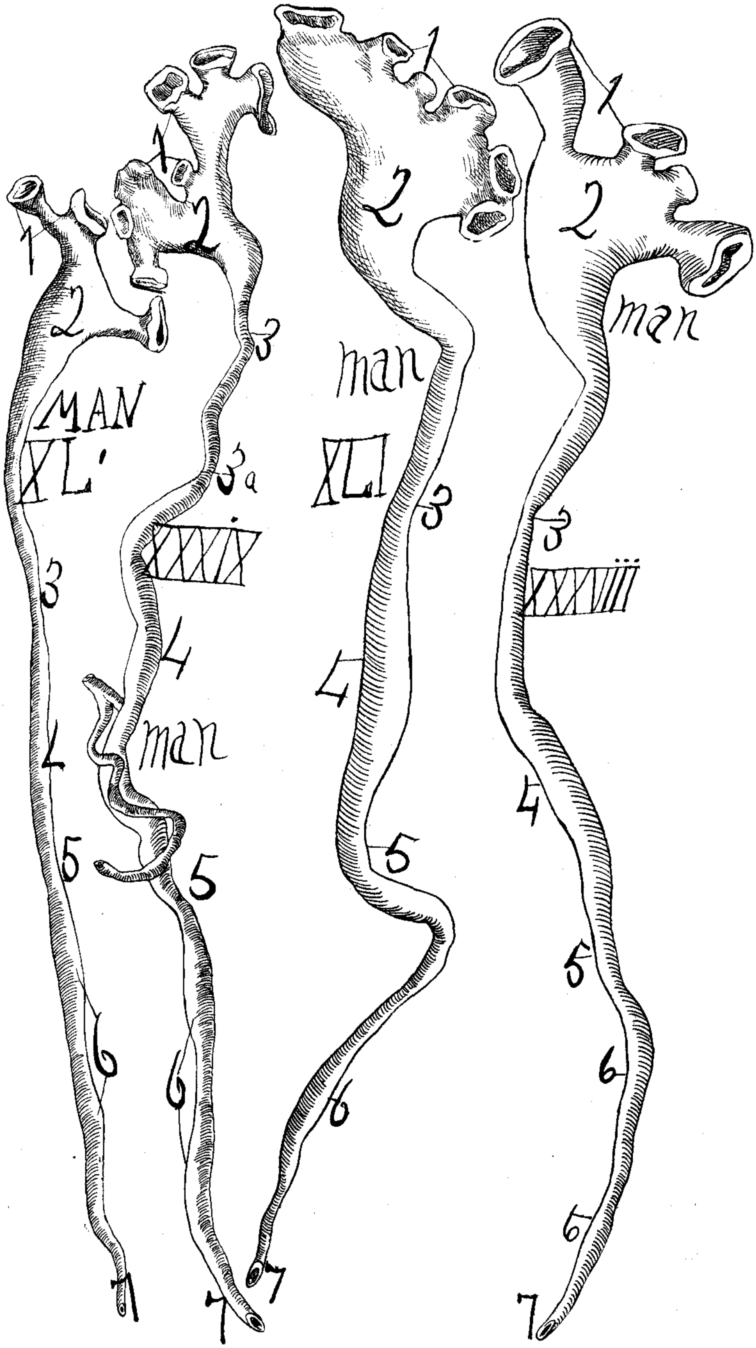

FIG. 18.—4. Ureters of man. The spindles and isthmuses of all are pronounced. Nos. XXXVIII and XXXIX are from the same male subject. Note the variation of the pelvis calices in the same subject. XL and XLI are from different subjects.

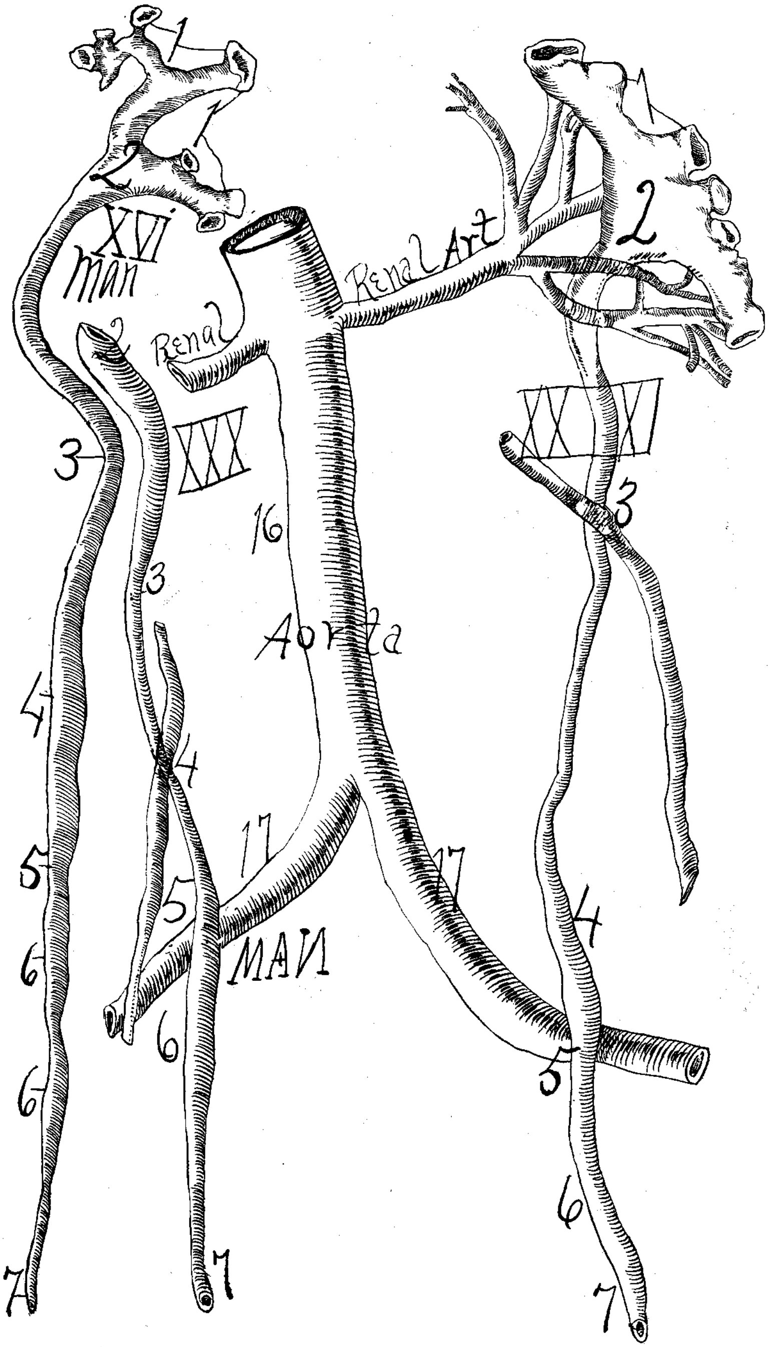

FIG. 19.—Nos. XXX and XXXI are from the same male subject, presenting the proximal and middle arterio-ureteral crossings at 3 and 5. XVI presents pronounced spindles,—two pelvic spindles at 6 and 6. The proximal arterio-ureteral crossing is generally more distally located on the right side, *e.g.*, 4 in No. XXX and 3 in No. XXXI (left side).

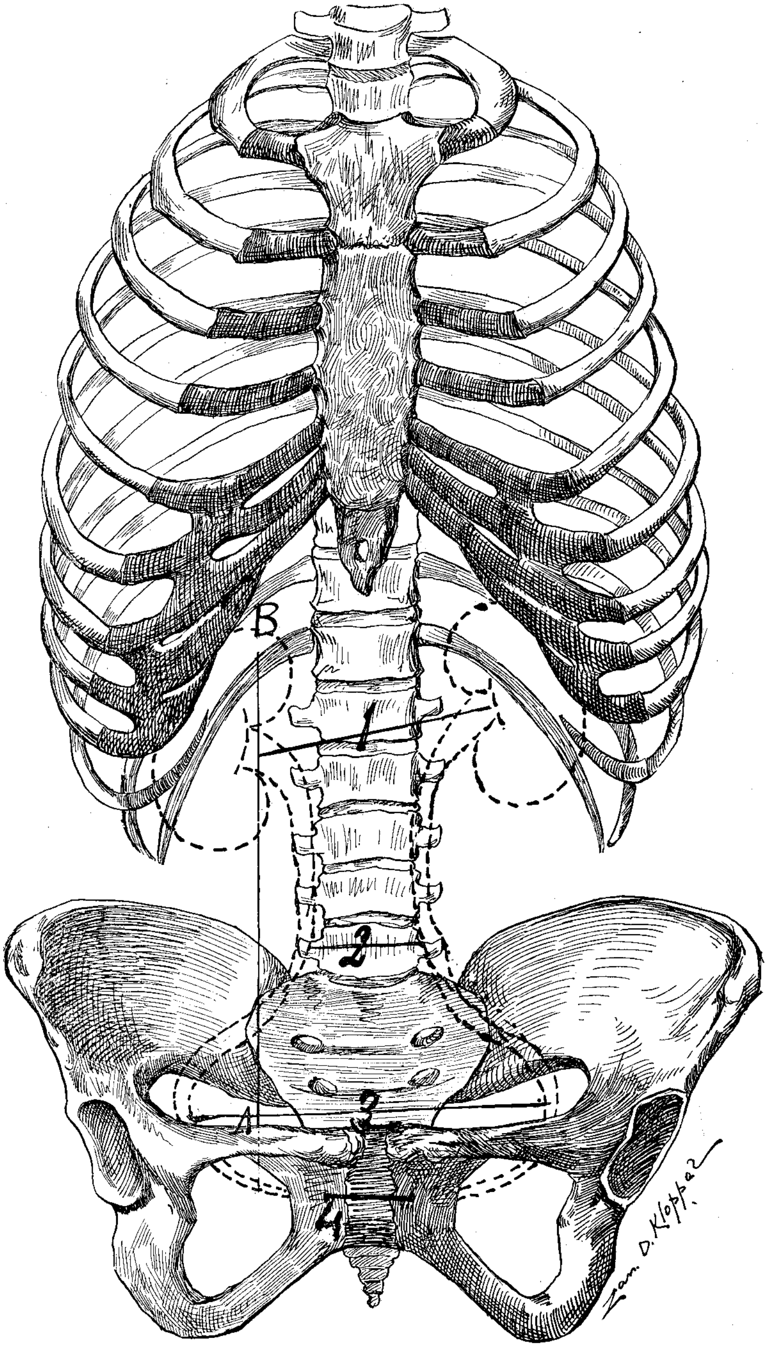

FIG. 20.—The course of the ureters on the dorsal skeletal wall. They lie ventral or in contact to the tip of the II and ventral to the ventral surface of the III, IV, and V transverse processes of the lumbar vertebræ. They curve in the region of the spina ischiadica 1. Distance between ureteral pelves (four inches). 2. Shortest distance between lumbar ureters (two and one-half inches). 3. Widest distance between pelvic ureters (four and one-half inches). 4. Distance between distal orifices of resting bladder (one inch).

mum separation of about four and one-half inches. The ureters and rectum are not parallel. The ureter follows the lateral pelvic wall, while the rectum follows the sacral curve. However, the ureters converge medialward at the pelvic brim, and at the pelvic outlet the distal ends of the ureter curve ventrally, while that of the rectum curves dorsally, the vagina and pudendum lying between the divergent rectal and ureteral extremities. The ureters approach the lateral and ventral rectal surface similarly with that of the vagina.

The relation of the ureter to the ligamentum latum is significant, because the ureter as it passes through the base of the ligamentum latum practically abandons peritoneal relations and penetrates the abundant pelvic subserosum. Hence the ureter courses through parametrium until it penetrates the bladder. The ureter at its distal end lies in a vast areolar bed, which is necessary for required wide range movements, changing volume and position of the tractus genitalis, tractus intestinalis, and tractus urinarius. The most mobile portion of the pelvic ureter is in the base of the ligamentum latum. The ureter during its course through the base of the ligamentum latum crosses the proximal part of the ligamentum teres uteri; however, the ureters and round ligaments are separated from each other by the plexus venosus vesico-vaginalis. The ureteral sheath is strong, thick, and vascular in the base of the ligamentum latum.

The relation of the ureter to the oviducal pavilion is significant on account of the frequent local peritonitis at the proximal end of the oviduct. The oviducal pavilion, with the ovary in the fossa ovarica, may lie directly on the ureter separated from it by the peritoneum only. Congestion, hyperæmia of the oviduct and ovary periodically (menstruation) or continually (gestation), salpingitis, and ovaritis might affect an adjacent segment of the ureter. Peritoneal infection is liable in 15 to 25 per cent. of subjects to invade the subperitoneal tissue ending in cicatricial contractions which induce constrictions and dilatations in the ureter.

The relation of the ureter to the ovary is important in surgical intervention. If the ovary occupies its usual position in the fossa ovarica, the ureter forms the distal border of the fossa and courses along the margin of the ovary. The free border of the ovary rests on the ureter separated from it by the peritoneum only. If the fossa ovarica is deep on the ureter or large, it may project a fold of peritoneum, a kind of meso-ureterium or the plica ureterica. In the extreme distal position of the ovary the relation of the ureter and ovary may be totally altered, whence the ovary may lie dorsal and distal to the ureter, which would then course along the meso-ovarial border. In the development of ovarian tumors, where the ovary was in the extreme distal position, the ureters may be forced by the tumor proximalward and lateralward. I have seen both ureters severed in a patient where the ovarian tumor forced the ureters proximal to the pelvic bone. The interesting report of the patient was that she recovered; that one ureter only discharged urine through the abdominal wound for six weeks; that after six weeks of complete occlusion of the other ureter by ligature which cut through the ureter, it began suddenly to discharge urine similarly to the other ureter. Hence the kidneys will retire from active service six weeks through ureteral ligation, whence it may resume secretion without apparent injury.

The relation of the ureter to Douglas's fold is not sufficiently intimate to be of much practical importance.

Vital.—Sufficient ureter to conduct urine to the surface mucosa or cutis is requisite for life.

Pathology.—1. The ureter is subject to bacterial disease, —inflammation.

2. The ureter is subject to stricture and dilatation.

3. The defects in the ureter are in peristalsis or obstruction of the urinal stream.

4. The ureter is subject to ureteral calculi.

5. The obstruction of the ureter may be from kink, torsion, stricture, or calculus.

6. Dilatation of the ureter may obtain the dimensions of

the enteron. Tuberculosis of the ureter may make it feel like a hard cord.

Age and Function Relations of the Ureter.—I. In *pueritas* (one to twelve years) the ureters are quite spiral in the lumbar segment. The ureters are almost suprapelvic, and hence the flexura iliaca exist to a slight extent only. In pueritas the distal ends of the ureter only partially enter the shallow pelvis; they are located more proximalward and dorsalward than in adults. The lumbar and pelvic spindles are limited in development. The ureteral blood supply from the arteria ureterica distal and proximal is limited from the limited development of the utero-ovarian artery or genital vascular circle. No periodic hyperæmia from genital vascular waves.

II. *Pubertas* (twelve to fifteen years of age). The ureters experience a vast increase of blood from the rapid development of the utero-ovarian artery and consequent increase in quantity of blood which passes through the arteria ureterica distal and proximal. The sudden increase of blood to the proximal and distal arterio-ureteral crossing may have influence in developing the size and capacity of the lumbar and pelvic ureteral spindles, especially as the spindles are more pronounced and sharply defined in woman than in man. The flexura iliaca ureteris rapidly increases from the development of the osseous pelvis and the distalward movements of the internal genitals and bladder. The pelvic ureteral curve, sacral and lateral, increases from the increased development of the os coxæ. The hyperæmia constantly increases towards the ureter through the arteria ureterica proximal and distal during the entire pubertas.

III. *Menstruation* (fifteen to forty-five years). The ureters experience a periodic congestion or hyperæmia at the proximal and distal arterio-ureteral crossings. The utero-ovarian artery rapidly develops as well as the arteria ureterica proximal and distal. The flexura iliaca ureteris increases with the development of the osseous pelvis and distalward movements of the internal genitals and bladder. The pelvic curve, sacral and lateral, of the ureter increases. The pelvic, but especially the lumbar, spindles become more pronounced.

IV. In *gestation* the hyperæmia of the ureter at the distal and proximal arterio-ureteral crossings becomes greatly increased from the mighty development of the utero-ovarian artery. This constant active blood supply must influence the size and capacity of the lumbar and pelvic ureteral spindles.

V. In *puerperium* (three to four months) the rapid decrease of blood from the proximal and distal arterio-ureteral crossings will unfavorably influence the nourishment of the walls of the ureter, especially in the regions of the spindles. At the proximal and distal arterio-ureteral crossings the ureter experiences an involution.

VI. In *climacterium* (forty-five to forty-eight years) the blood supply to the distal and proximal arterio-ureteral crossing is lessened and irregularly periodic.

Arteriosclerosis, calcification, begins with defective nourishment in the regions of the ureteral spindles; a tendency to ureteral dilatation arises. Ureteral parenchymatous cell (muscle, elastic, and epithelium, functionating cells) degeneration now appears, with increase of connective tissue, framework cells. The malnutrition results in irregular thickness of the ureteral wall and irregular dilatations.

VII. *In senescence* (forty-eight to termination of life) there is no hyperæmia at the proximal and distal arterio-ureteral crossings. Arteriosclerosis and calcification arise in the proximal and distal arteria ureterica. Pathologic degeneration of ureteral parenchymatous or functionating cells (muscle, epithelium, elastic) and increase of frame-work or connective-tissue cells occur in the regions of the proximal and distal arteria ureterica. Arteriosclerosis and calcification with consequent malnutrition of the ureteral wall results; irregular ureteral dilatation, especially in the regions of the proximal and distal arterio-ureteral crossings, *i.e.*, in the region of the spindles. The irregular ureteral dilatations found in senescence bear out age and functional relation of the ureters in woman. The irregular ureteral dilatations normal or pathologic are more pronounced in woman than in man.

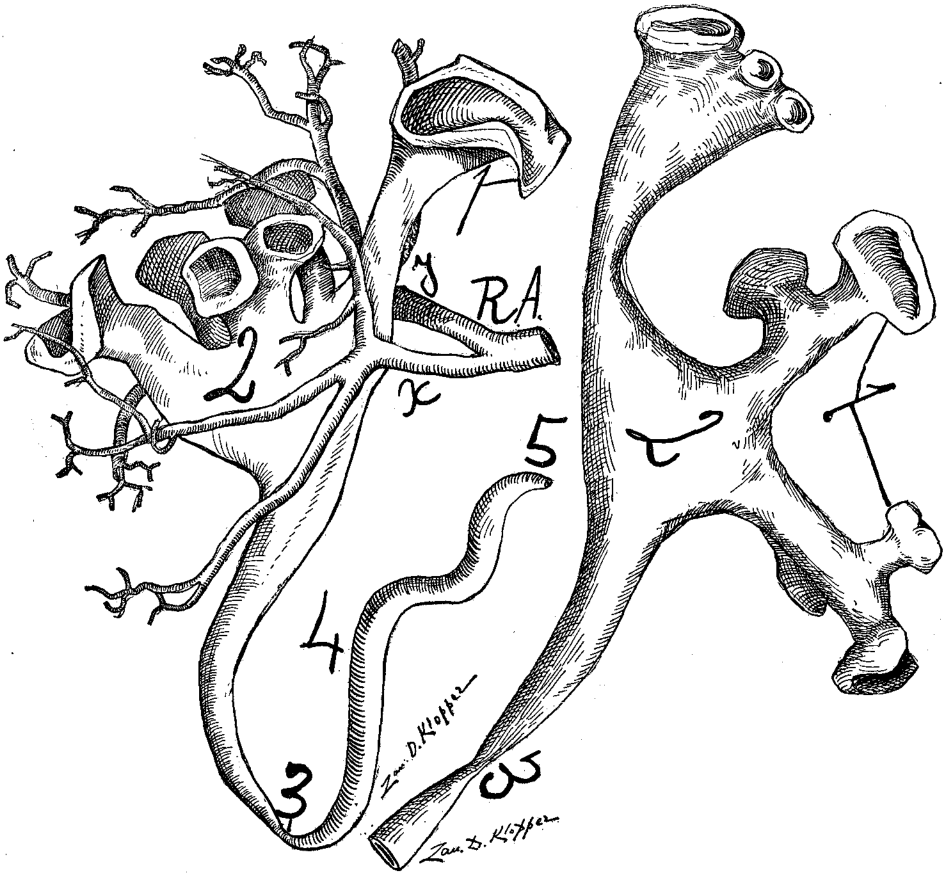

FIG. 21.—A drawing of a paraffin cast of the ureteral calices and pelvis made by the author in 1892. 1. calices; 2, pelvis; 3, proximal ureteral isthmuses (figure to right).

Figure (to left). Drawing of paraffin cast of ureteral calices, pelvis, and renal vessels. I injected melted paraffin into the ureter and renal vessels; placed it in HCl for a week; washed it in slow running water, and my artist, Mr. Zan D. Klopper, drew from it as a model. 1, calices; 2, pelvis; 3, proximal isthmuses; 4, lumbar spindle; 5, middle isthmus. Note spiral ureter. Corrosive anatomy demonstrates, a, the kidney has a double circulation; b, the ventral renal arterial branch (y) is the larger; c, the vascular anastomotic line of the ventral and dorsal segments of the kidney lie dorsal to the external median line of the kidney (this line I shall term Hyrtl's exsanguinated renal zone); d, the line of renal incision for renal calculi should be made dorsal to the external median border when hæmorrhage is simply capillary. I have employed this method in practice with satisfactory results. RA. Arteria renalis. Y. Ventral branch of arteria renalis. X. Dorsal branch.

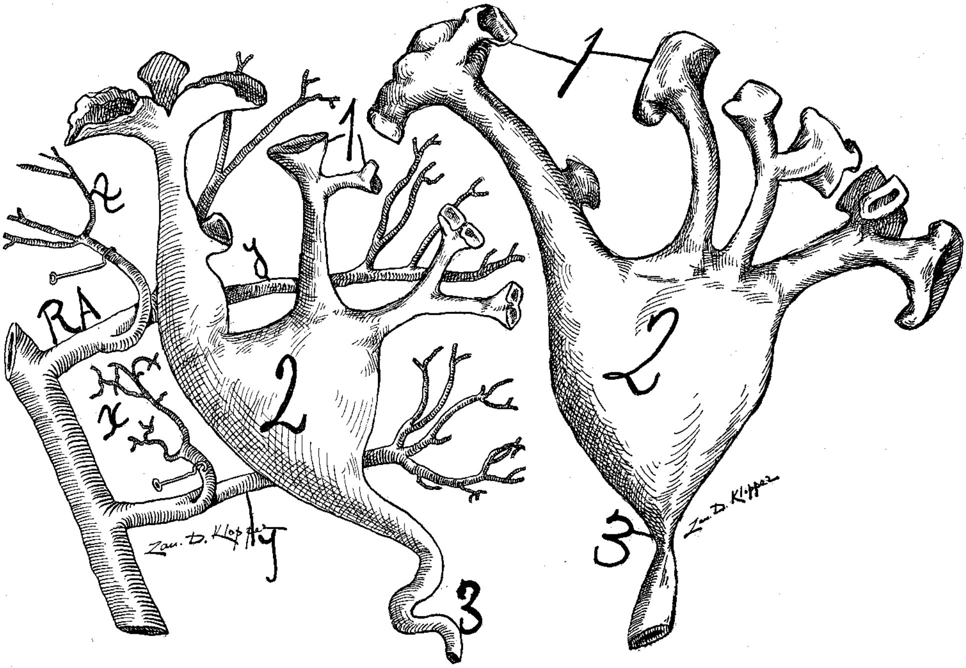

FIG. 22.—Paraffin cast of ureter and renal vessels. Prepared by the corrosive method and sketched from it as a model. 1, calices; 2, pelvis; 3, proximal isthmus. Observe spiral in ureter. Note the larger ventral (y) and smaller dorsal (x) renal arterial vessel. The renal vessels inclose the calices and pelvis within their grasp. The hook draws the dorsal renal branch (x) from the calices to allow the pelvis to be viewed.

Figure (to right). Paraffin cast of: 1, ureteral calices; 2, ureteral pelvis; 3, proximal ureteral isthmuses.

A comparison of forty-five ureters here presented as to calices (1), pelvis (2), isthmuses (3, 5, and 7), and spindles (4 and 6) will reveal a wonderful variation as to the shape, size, location, and multiplicity.

CONCLUSIONS FROM STUDIES OF THE URETERS.

1. The ureter is not a uniform calibered tube.

2. It consists in general of three isthmuses or sphincters located at points in the ureter where projecting adjacent structures compromise; kink its lumen. The ureteral lumen is compromised by: (*a*) the distal renal pole projecting the ureter medianward, producing what I shall term the proximal isthmus, sphincter or neck of the ureter; (*b*) the ureteral lumen is compromised at the point where the vasa iliaca project the ureter ventralward, producing what the author terms the middle isthmus or sphincter, the flexura iliaca ureteris. The middle ureteral isthmus is due to the increased ventral projection of the ureter by the vasa iliaca on assuming the erect attitude (man, erect bimana). Quadrupeds do not possess the middle ureteral isthmus, and consequently less lumbar ureteral spindle. (*c*) The lumen of the ureter is compromised at the point where its distal end penetrates obliquely the muscular wall of the urinary bladder.

3. Compromised lumen by isthmuses or sphincters induce ureteral dilatations—reservoirs or spindles. There is a ureteral reservoir proximal to each ureteral isthmus, *e.g.*, (*a*) ureteral pelvis proximal to the proximal isthmus or neck; (*b*) lumbar spindle proximal to the middle ureteral isthmus; (*c*) pelvic spindle proximal to the distal ureteral isthmus in its vesical wall.

4. The ureteral spindles are more pronounced in woman than in man on account of the proximal and distal arteria ureterica having an excessive or periodic hyperæmia during reproductive life (pubertas, menstruation, gestation, puerperium, and climacterium). Consequently, in senescence, when its proximal and distal arteria ureterica becomes affected with arterial sclerosis or calcification, lack of nourishment will induce pathologic dilatations of the lumbar and pelvic spindles.

5. Calculi lodge at the ureteral isthmuses.

6. Torsion of the ureter or kink may easily compromise the ureteral neck or proximal ureteral isthmus.

7. Surgical interventions on the ureter should be performed at the ureteral reservoirs or spindles on account of ample lumen and wall.

8. Pathologic conditions of the ureter lie mainly in defects of the ureteral wall (inflammatory products, paresis, tuberculosis, etc.) producing deficient peristalsis, or in the mechanical obstruction to the ureteral stream (calculus, kink, torsion, stricture).

9. So long as the ureteral peristalsis is not interfered with, and especially the ureteral stream is not obstructed, the ureters perform their function.

10. However, as soon as any mechanical obstruction to the ureteral stream arises (as kink, calculus, stricture), the non-drainage induces residual deposits with resulting accumulations of bacteria, whence the vicious circle occurs in the tractus urinarius exactly similar to vicious circles arising from obstructions in the pylorus or the biliary ducts.

11. The ureter is an independent organ conducting the urine from the kidney to the bladder by rhythmical waves, regardless of altitude or force of gravity. It is an elongated duct interpolated between kidney and bladder with similar functions to the bladder—a reservoir.

12. The ureter being located in a universally loose areolar bed, and being longer than the distance between its proximal and distal ends, is capable of an extensive range of motion in pathologic conditions or for surgical intervention.

13. The irregular caliber of the ureter, dilatations (reservoirs, spindles), and constrictions (isthmuses, sphincters) is an hereditary heritage from the Wolffian body enhanced by environments.

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